New England Water Works Association.
ORGANIZED 1882.

Vol. XXXI. June, 1917. No. 2.

*This Association, as a body, is not responsible for the statements or opinions of any of its members.*

# PUBLIC-SERVICE REGULATION.

BY THOMAS W. D. WORTHEN, COMMISSIONER, NEW HAMPSHIRE PUBLIC SERVICE COMMISSION.

[*Read January 17, 1917.*]

From early times, common carriers and industries classed as public utilities have nominally been subject to regulation by common law, but the remedy has been ineffective on account of the expense and delay involved in bringing suits and getting decisions. The conduct of some of our railroads and other public-service corporations in excessive issues of stock, discriminations, inadequacy of service, etc., finally incited the public to demand that a tribunal more available than the court for securing fair relations between the public and these corporations be established. This resulted in a widespread determination to make the so-called public-service corporations the actual servants of the people by the enactment and enforcement of laws regulating the conditions of operation, the service rendered, and the charges to be made therefor. In some localities, a spirit of antagonism was aroused so that the corporations welcomed the establishment of a tribunal of ready reference for the settlement of differences connected with public service.

It was not until 1906 that large authority was given to the Interstate Commerce Commission. In 1907, Wisconsin and New York included the utilities in their field of regulation and appointed very efficient boards of commissioners. Massachusetts had already taken a step in advance in the appointment of a gas com-

mission in 1886. The work of these commissions has been epoch-making, and since 1907 the regulation and control of public-service corporations* has been entrusted to commissioners in forty-six states of the Union, — all except Delaware and Utah. The spirit of antagonism and retaliation which was manifested in some cases is no longer in evidence to any considerable extent, and in general a spirit of fairness prevails in the general public, the commissions, and the corporations.

It is pretty generally agreed that there can never be a return to competition to regulate prices in the public-service field. The experiment of public regulation is now being tried almost universally in this country, and, if it proves satisfactory to the masses, it will be permanent, and all depends on whether the masses take sufficient interest to make sure that suitable men compose the commissions. If regulation fails, public ownership is inevitable; and, for this, very high standards in theory and practice of the duties of citizenship are required. Regulation of public-service corporations should secure and maintain fair and just relations between those rendering the service and those served. This means for the public as good service as can reasonably be furnished at as low a price as is fair to the producer, and free from undue discrimination.

The industries or corporations classified as public-service corporations are usually arranged in two groups: First, railroads, which include steam and electric railroads and car and express companies. Second, utilities, which include gas, electric, telegraph, telephone, and water companies, and, in some states, toll bridges, ferry and other boats used in public transportation of passengers or freight, warehouses, etc. This classification applies to individuals and partnerships as well as corporations. The regulating boards in the various states are designated as railroad commissions, corporation commissions, public utility commissions, or public service commissions. The number of members is usually three or five. They are appointed in twenty-five states and elected in twenty-one states. The terms of office range from

* A single public-service plant of each variety is ordinarily adequate to serve a community, and a duplication involving unnecessary investment must inevitably require a larger revenue to carry on the business.

two to seven years. The salaries range from $1 500 to $15 000 per year. The number of subordinate employees ranges from one to six hundred. Every up-to-date public-service act authorizes the commissions to confer in person, by attending conventions, or otherwise, with the members of the commissions of other states and with the Interstate Commerce Commission, on any matters relating to public utilities.

As a full understanding of all the conditions involved is necessary in order to insure justice in any case, a commission Act contains a section to the following effect:

"The commission or any commissioner or any person or persons employed by the commission shall upon demand have the right to inspect or examine the books, papers, accounts, documents, plant, property, and facilities of any public utility and to examine under oath any officer, agent, or employee of said public utility in relation to its business and affairs."

In this as in general, much depends on the spirit and manner in which the work is carried out. When it is recognized that it is done in the best interests of all parties, no friction is occasioned.

## Accounts and Reports.

One of the first undertakings of every commission is to secure from each utility as full a report as possible of the character and extent of the plant or investment, and the character and extent of the operations. In this, as in all other lines of public-utility regulation work, the Wisconsin and New York commissions have done pioneer and extensive work. It is necessary in the first instance to send out comparatively simple forms to the various utilities, indicating the exact information desired. Our experience in this connection may be of interest. We sent out such forms and were greatly surprised at the lack of accounts to show cost of operation, plant investment, etc. It required a large part of the time of a clerk for a full year to get the reports in, and into such form as to make possible any comparison whatever of the operations of utilities of the same class. A great amount of work was done by correspondence, and a considerable number came to Concord to be personally conducted in making up their reports. The reports of the utilities for the second year were less than fifty per cent.

ready for printing when filed, and it was evident that a uniform system of accounts and records must be adopted. Comparative statistics of what has been done by the various utilities are essential for progress in efficiency. Ours is a *public*-service commission. Whenever it takes up a question of public interest it invites all who are involved or interested to meet in a public conference, so as to be sure to get all points of view. After securing legislative authority, we set about the considerable task of setting up a standard system of accounting adjusted to various conditions of the different utilities. It was done in this way: A tentative scheme was set up and distributed to the utilities. Electric utilities were taken up first. Criticisms and suggestions were requested. Three public meetings were held for discussion. The National Electric Light Association was represented, and careful comparison was made with the accounting system then under preparation by a committee of that association and already in use by several electric companies, so as to avoid minor differences not essential to the securing of the information deemed necessary for our record. Comparable schemes for four grades, A, B, C, and D, were adopted, and finally there was general agreement that the records were such as ought to be kept for the benefit of the companies themselves. Gas and water utilities were treated in like manner. Steam and electric railroads, express, telephone, and telegraph companies are in charge of the Interstate Commerce Commission, and blank forms with instructions are available for state use with modifications for local needs. In this way there is made available in convenient form the information necessary for a comparative study of like companies, which by making evident any lack of efficiency will be an aid toward uniform excellence in operation. I am sure that municipalities operating utilities will find these systems of accounting very helpful, and it would be very useful to the commissions to have records of the operation of utilities by municipalities available.

### Adequacy and Safety of Service.

In general, the public-service law requires that the service and facilities of every public-service corporation shall be reasonably adequate and safe, and every service rule and practice shall be

just and reasonable, and it is made unlawful for any public-service corporation to make or permit to exist any unjust discrimination or undue preference with respect to its service or facilities.

The first requisite for any effective regulation under this article is to establish adequate standards of quality of service rendered or to be rendered by each class of public utilities, and to prescribe regulations for the examination and testing of the service and provide for the inspection of the manner in which each utility conforms to the regulations prescribed by the commission for the examination and testing of its service, and for the measurement thereof. Provision is made for the calibration, checking, or standardization, to secure the accuracy of measuring instruments used by any public utility, and in so doing the plan is to conform as closely as possible to the standards and methods of standardization of the National Bureau of Standards at Washington. I will give our experience in this connection.

Our first service complaint was in regard to gas, "quality poor," "price high." It was so, and it was remedied without formal hearing and with very substantial saving to the community.

After securing full legislative authority, gas utilities were first considered by the commission. The gas then being produced by the different companies was tested for heating value, pressure, and impurities, to determine the conditions then existing. A tentative set of rules was prepared and a conference held at which the various gas companies and the Bureau of Standards of Washington were represented. A set of rules was adopted which was considered reasonably fair, both to producers and consumers. The rules adopted prescribe standards of purity, pressure, and heating value of gas, and provide for periodic testing thereof, and for the testing of meters and for regulating the service of gas utilities in other ways.

Standards of service have also been established for electric, water, and telephone companies, and general improvement in service is expected. Much of the poor service was due to the fact that many utilities had no way of testing the quality of their service. Some consideration may be necessary while the regulations are being put into operation, but it devolves upon the utility to show the commission that a modification of some rule

or rules should be made in fairness to the utility. I am sure that these standards of service would be helpful to municipally operated utilities.

## RATES.

The first general communication from our commission to the utilities was a request that all schedules of rates and all rates and contracts not scheduled be filed with the commission within a reasonable time. One utility reported, "We have no schedules, we take whatever anybody is willing to give us"; but in explanation he said, "Our policy is to take all the business we can get and get as much as we can out of it."

Formal complaint was made to the commission that an electric utility did not make out its bills according to the rate schedule. The investigation disclosed that the utility used no fixed schedule. The method was to decide how much money was wanted and make out the bills accordingly.

Frequently a utility was saddled with rates made for the purpose of securing customers or favorable influence, or under pressure of various kinds, and it was not able to revise the schedule and make rates equitable without serious friction. Much of the work of adjustment is done by correspondence or conference, but occasionally cases require formal proceedings, investigations, and orders. Extreme cases are likely to be brought to the notice of the commission by petition or to attract attention in the consideration of capitalization or transfer cases, or in the comparison of the operation of utilities of the same class. Changes in schedules are very likely to be objected to, particularly if any rates are raised, which is usually the case when some customers have been enjoying specially low rates. Hence, utilities hesitate to change their schedules, although they are well aware that they are not just and equitable, and prefer to await the order of the commission. On the other hand, it is not a very uncommon thing for a company to carry out some scheme on its own motion and give as a reason that it is required to do so by the Public Service Commission.

All schedules of rates must be filed with the commission and posted in the main office of the utility or railroad, and all changes must be treated as schedules before they are made effective.

## Rate Theory.

(A large part of what follows on rate theory and practice was prepared as a report to the National Association of Railway Commissioners.)

The usual statutory requirement is that all utility rates shall be just and reasonable. Just and reasonable rates are described to be such rates as produce a fair return on the fair value of the property in use and useful in carrying on the business, and, further, such rates as are free from preferences or undue discriminations between persons, localities, commodities, or classes of service. The same principles underlie utility and railroad rates, and these are clearly set forth in Smyth *v.* Ames (169 U. S. 546, 547):

"The utmost that any corporation operating a public highway can rightfully demand . . . is that it receive what under all the circumstances is such compensation for the use of its property as will be just and reasonable both to it and to the public.

"The basis of all calculations as to the reasonableness of rates . . . must be the fair value of the property being used by it for the convenience of the public.

"What the company is entitled to ask is a fair return upon the value of that which it employs for the public convenience. On the other hand, what the public is entitled to demand is that no more be exacted from it for the use of a public highway than the services rendered by it are reasonably worth."

Hence, at the outset of any rate study or investigation, it is necessary to determine the fair value and the fair rate of return as applied to the particular case under consideration.

## Fair Value.

Volumes have been written on this subject, and as yet no fixed and definite principles have been generally accepted which reduce the work to the realms of arithmetic or even mathematics in general. Some one has said that the real problem, mathematically speaking, is to reduce the percentage of guesswork to a minimum. In many cases that is true. When the plant is of recent origin, or the books have been carefully kept from the beginning, so that the original cost can be ascertained and the amounts expended in extensions can be distinguished from the ordinary re-

pairs, which should be taken care of as part of the operating expenses, the actual cost to date can readily be found, and this is generally regarded as very important information provided there is reason to believe that it was wisely conceived, and that construction was properly made. Some regard this as the only thing to be considered when it is available. In most cases, however, the early books have been lost or they have not been so kept as to show the actual cost to date. The cost of an identical plant at date, or the cost of reproduction new, with allowance for depreciation, is regarded as an important factor, especially when actual cost cannot be discovered. The proper presentation of a modern scheme of cost of reproduction new would require much more time than we had at our disposal at the start. Some claim that property devoted to the public service is like any other property in this, that it is worth all it will sell for. Some would consider the capitalization, some the tax valuation, as having weight in determining fair value.

It has been well said that "the valuation of public utility undertakings is a mixed question of fact, judgment, and law." It has also been well said that "fair value must always be determined by the well-instructed judgment of a broad-minded and impartial tribunal." In this connection, reference is made to an excellent paper on "Rates for Water Supply,"* by B. M. Wagner.

## Fair Return.

The amount of return should be such as to provide for the cost of economical and efficient operation, taxes, and depreciation, a fair net return on the fair value of the property devoted to public use, and a proper margin for the successful conduct of the business. Exceptional efficiency of management should receive consideration and encouragement.

## Cost of Operation.

Cost of operation requires careful attention in rate questions; and in establishing a rate system, competent engineers and accountants must make such investigations as to determine ac-

* Journal N. E. W. W. A., XXIX, 1.

curately the degree of economy and efficiency with which the business is conducted.

### Taxes.

The matter of taxes requires only to be noted, but attention is called to the fact that there is often an unjustifiable difference between the valuation on which taxes are paid and that on which rate of return is allowed. Ordinarily, these should be identical except in the case of property not useful to the service.

### Depreciation.

The fair amount to be set aside for depreciation varies with local conditions, and can be determined only by a careful accounting for a long term of years. The extent to which replacements are included in operating expenses, and the thoroughness of the repairs and upkeep of the plant, have an important bearing on the additional amount necessary to be set aside to safeguard the investment.

The composite life of the plant, determined from the probable length of life of its various parts, gives a percentage which is taken as a working basis, and should be subject to such modifications as experience requires.

Example: If the composite life is found to be thirty-three and one-third years, giving a depreciation rate of three per cent. on a straight line basis, and replacements to the amount of two per cent. are included in operating expenses, only one per cent. additional would be assigned to depreciation.

Rates for depreciation allowed by commissions generally range from one per cent. to six per cent., according to conditions.

### Rate of Net Return.

Fair rate of net return varies widely with local conditions. In general, the legal rate of interest may properly be taken as a standard of measure of the fair rate of net return to be distributed to the stockholders, but this may require modifications to fit cases which are exceptional in the amount of risk connected with the investment. When a business is of a permanent and stable character, and is free from irresponsible and destructive competi-

tion, the rate of net return may well approach that on bond and savings bank investments; and, on the other hand, when an exceptional element of risk pertains to the business, as in obsolescence of plant or obvious possibility of competition of other substitute service, a rate substantially above the legal rate of interest may fairly be allowed. (The legal rate of interest is five per cent. in three states, six per cent. in thirty-one states, seven per cent. in eight states, and eight per cent. in six states.)

Rates of net return allowed by commissions range in general from five per cent. to eight per cent., but, in municipal plants, rates ranging down to four per cent. have not been declared confiscatory, and as high as ten per cent. rates have been allowed in a few instances. There is a considerable twilight zone between a rate of return that would be declared confiscatory and the minimum rate of return that would be regarded as reasonable.

It must be borne in mind that there is no necessary relation between the stock and bonds outstanding and the fair value of the property. When the amount of stock equals that of the bonds, and they together equal the fair value of the investment, — a desirable but rare state of affairs, — the lower rate on the bonds allows a higher rate on the stock; e. g., if in such a case a six per cent. net rate of return is allowed on the fair value of the investment, a bond rate of four and one-half per cent. would allow a seven and one-half per cent. rate on the stock. The rate of net return allowed should be such that new capital may be available for extensions and improvements necessary for the proper development of the business.

### Business Encouragement.

Some allowance should be made in rate of return authorized as well as in the rate of dividends distributed when necessary, in order that the business may become firmly established with a substantial surplus within a reasonable length of time. It is important to encourage economy and efficiency of operation.

A special effort in this direction has been made in Massachusetts during the last ten years. In 1906, the Massachusetts legislature authorized the adoption of an automatic and interdependent adjustment of the price of gas to consumers and the rate of divi-

dends to stockholders, known as the London Sliding Scale. This system was applied to the Boston Consolidated Gas Company. The standard price of gas was fixed at 90 cents and the standard dividend at 7 per cent., and for every five cents reduction in price an increased dividend of one per cent. was allowed. Under this arrangement, the price of gas was reduced to 85 cents in 1906 and to 80 cents in 1907, and the dividends paid were eight per cent. in 1907, nine per cent. in 1908 to 1913, eight per cent. in 1914, and eight and one-half per cent. in 1915. The subject was investigated in 1915, and the commission reported conditions not satisfactory, insufficient reserve for depreciation, and dividends not fully earned from sale of gas, and further extension of the plan was not recommended. The case was complicated by the combination of various companies, including a holding company, so that no final conclusion as to the advisability or workability of such a scheme was reached. It is, however, a sound business principle worthy of general adoption "that decreased cost and increased profits due to skillful and wise mangement shall be shared in lower prices to the public and higher dividends to the stockholders."

## Rate Bases.

Having determined the fair value of the property devoted to the public use and the fair amount of return to be allowed thereon, a third exceedingly difficult problem remains, — namely, the fair distribution of the charges to be made.

Equitable rates are defined as "such as will assess the proper gross income upon consumers without discrimination and with due regard to the public interest."

The two bases of rates are:

1. Cost of service, under which each consumer is charged in exact proportion to the cost of service rendered.

2. Value of service, under which each consumer is charged what the service is worth to him, which in many cases is the price necessary in order to secure an equivalent service. It is a generally accepted principle that each class of consumers shall, so far as possible, bear its share of the costs incurred in serving said class, and pay its share of the profit necessary in order that the rendering

of such service may be a successful business enterprise. The minimum charge cannot be less than the service costs, as business cannot be done at a loss, and the maximum charge cannot be more than the service is worth to the consumer, as he will not pay more than it is worth to him. The adjustment of the rates to the varied types of service may not be determined theoretically, as a perfect theoretical schedule might fail utterly in practice, through the fixing of rates for some varieties of service so high as to be prohibitive. The details of railroad and utility schedules must be determined on business principles and adjusted to local conditions. The object to be sought is the best and largest service possible to all classes of consumers at the lowest practicable rates.

The cost of serving different classes varies widely, as also the value of the service to the customers, and the schedule of rates must recognize the local business conditions in each case.

As in fixing commodity freight rates, the problem often is to determine whether freight rates which will permit the commodity business to be established and carried on are sufficiently remunerative to justify the railroad in rendering the service. So in power service the question often is whether the electric company can supply the power at the rate which the customer can afford to pay or at which substitute power can be obtained with a net gain above the actual cost of rendering the service.

There are a considerable number of earnest advocates of uniform rates on the theory that each unit should be furnished at the same price by the same producer to every customer. On the cost-of-service theory alone, this would sometimes be correct, and it requires very careful consideration in all cases. In electric business, particularly, the cost of rendering a unit of service varies daily. The expenses are practically constant, and the output of units varies. Ordinarily, in a hydro-electric plant a large additional day load may be taken on at slight additional cost. The peak load users are regarded as responsible for the size of the plant, as it is required for their service, and it is the common practice to seek day customers even at much lower rates.

It is an important question of public policy whether exceptionally low rates shall be made for large service, not otherwise available, which would result in large additions to income and

some net profit. Thus far the practice has been very prevalent to make industrial or wholesale rates often without due regard to the cost of rendering the service. This practice requires very careful attention, as there is always danger that the independent large user will not bear his fair share of the cost of rendering service.

## Rate Classification.

Schedules of rates should be in such form as to be easily understood, and those for the same class of service should be in the same general form, so that comparison of rates may be made.

The principal types of rates are:

### 1. Flat rates.

Under this system a fixed sum is to be paid annually, semi-annually, quarterly, or monthly. Flat rates have been based on various conditions of service, such as the frontage of the house or lot, valuation for taxation, floor area of building, number of sleeping rooms, number of persons, and number and character of fixtures. The evident inequalities in all these methods have led to an increasing adoption of the meter system or to the use of the meter as a check upon the inequalities or abuses to which any flat-rate system is liable. The extreme simplicity of this form has caused its retention and present use. When the actual use is for a known time, and also in the case of small users, this type of schedule is found to be quite satisfactory, especially when based on the number and character of the fixtures. But for long and short time users, or peak load and non-peak load users, this form of schedule has been found to be very unsatisfactory.

### 2. Meter rates.

Under this system the charge is based on the number of units of service rendered. Uniform meter rates afford a very simple form of schedule, and such a system is satisfactory when the conditions of use are practically the same for all customers. The principal objections to this method are that it does not encourage large use of the service, and that often the price is prohibitive for large business or manufacturing purposes.

Variable meter rates, in which the price diminishes with the

increase of the quantity used in blocks or groups of units, is in most common use in electric, and is frequently found in gas and water rates. Such a system is often made unfair to the long-time small user by making the first block so large as to require all small users to pay the maximum price. In two-block systems the charge for the first block is often made comparatively high, to cover demand or installation costs, and the charge for the second block very low, to induce large industrial or other use.

### 3. TWO-CHARGE RATES.

This system is based on the theory that each customer is to be held responsible for that part of the operation and plant investment costs necessary in order that the utility may stand ready to serve him, as well as for the number of units of service actually furnished to him.

This system is a combination of flat and meter rates. The flat or " demand " rate bears some relation to the installation or the amount of service which the utility must stand ready to furnish at the demand of the customer, and the meter charge is based on the units of service actually rendered. When the demand charge covers the fixed charges, the service charge is based on the cost of production. The service charge may then be a uniform charge at a moderate price or a variable charge arranged on a block system. A two-block system based on the use of the maximum demand is a very fair and satisfactory system, as the long-time small user is placed on an equality with the long-time large user, which is not the case in a common block system based on the first 10, 20, or 50 or more units. This type of rate is readily adjustable to short-time or part-year service, and is destined to wide use when a simple and accurate method of determining demand is available.

### 4. THREE-CHARGE RATE.

The cost of conducting utility business may be classified under three heads:

1. Customer charges, varying with the number of customers, such as meter care and reading, billing, postage, collections, etc
2. Demand charges, varying with the size of installation.
3. Service charges, varying with the actual service rendered.

In conducting a large business, it is desirable to arrange expense accounts in these three groups, and this method of classification naturally leads to a three-charge rate. Theoretically, this is the most complete and satisfactory type of rate, but it involves so many practical difficulties in application that it has been adopted by comparatively few companies. It forms the fairest basis for a check on any other schedule of rates when the business is on a large and varied scale. Under this system the bills consist of a comparatively small charge for customer costs, and varying charges for demand and service costs.

## Minimum Bills.

The large number of very small users has led most utilities to include a minimum bill in their rate schedules. The object is to prevent dead investment. The minimum bill usually includes customer costs and an allowance for the average amount of consumption by those paying minimum bills. It safeguards, to some extent, the investment and expense involved in standing ready to serve each customer. The justness of such a charge is generally recognized, but there is difference of opinion as to whether it should be a monthly or an annual charge, a flat rate for each class, or depending upon the demand or installation of each consumer. Under a meter system, a reasonable minimum charge is a reasonable precaution against loss. When bills are payable monthly, minimum bills are so collected, but when the actual consumption for the year exceeds the sum of twelve minimum bills it is thought that adjustment should be made on the ground that the object of the minimum bill has been secured.

It seems decidedly unfair for one who pays large bills for ten or eleven months in a year to be charged a minimum bill for a month or two when absent, and this is sometimes provided for by waiving minimum bill on notice of intention to be absent.

Flat-rate minimum bills are in common use, but it does not seem fair to have the same minimum charge for a demand of 250 and 2 500 watts or for a $\frac{5}{8}$-in. and a 2-in. meter.

In a few cases only have state commissions considered the question of yearly or monthly minimums. The Massachusetts Gas and Electric Commission in the Boston Edison Electric case or-

dered a minimum charge to be adjusted on an annual basis, so also the New York Second District Commission in the Buffalo Electric case, and the Maryland Commission in the Baltimore case. The New York Second District Commission said: "The minimum rate should be a yearly minimum and not a monthly minimum. The proper proportion should be charged monthly, however, and an adjustment made at the end of the year." The New Jersey Commission said "that the making of this minimum] charge by the month is just and reasonable and is really more equitable than if the charge were made by the year." The Wisconsin Commission said: "As to whether the minimum bill should be placed on a monthly or yearly basis, much can be said on both sides. In the instant case, however, it seems advisable to leave it on a monthly basis." My present impression is that minimum bills should include something more than actual "customer" costs, and be on a yearly basis.

### Discriminatory Schedules.

Before utility rates were placed under commission control, discriminatory rates were universally prevalent, and it is estimated that at least one fourth the schedules now in use violate the long-and-short haul principle. Some of the more common forms are:

Sliding scales, or "step" schedules, in which the larger includes the smaller amount as:

1. "Bills of $5.00 to $10.00 — 5 per cent. discount.
   Bills of 10.00 to 15.00 — 10 per cent. discount.
   Bills of 15.00 to 20.00 — 15 per cent. discount.
   Bills of 20.00 and over — 20 per cent. discount.

In this schedule a bill of $20 calls for only $16 in settlement, while a bill of $19.90 calls for $16.91; a bill of $15 for $12.75, and one of $14.90 for $13.41, etc. Such schedules are sometimes made less objectionable by adding the proviso that "the maximum charge under any per cent. of discount shall not exceed the minimum charge under the next higher per cent. of discount."

2. "To consumers of less than 50 000 cu. ft. per month, $1.20 flat per 1 000 cu. ft.
   To consumers of more than 50 000 cu. ft. per month, $1.10 flat per 1 000 cu. ft."

Under this schedule a consumer using 49 900 cu. ft. pays $59.88, while a consumer using 50 100 is charged only $55.11, i.e., by using 200 cu. ft. more, the bill is reduced $4.77. Such schedules may be improved as above, or by the proviso that "the minimum charge under any per cent. of discount shall not be less than the maximum charge under the next lower per cent. of discount."

Such schedules have been disapproved by various state commissions, and they should be superseded by block or other proper form of schedule.

### Prompt Payment Discount.

It is a common practice to adjust schedules to a discount for prompt payment, the rate of discount varying from five per cent. to twenty-five per cent., ten per cent. being most common, and the time limit ten or fifteen days. This appears to be a good working plan, and decidedly preferable to the scheme of adding five to ten per cent. as a penalty, if the bill is not paid in ten or fifteen days following the date of the bill. A sliding discount to large users is sometimes conditional on prompt payment. Such a schedule meets with general disapproval, and should not be allowed.

### Electric Rate Schedules.

The development of rate theory and practice already outlined has been mainly occasioned by the marvelous progress in the extent and variety of use of electricity. Since electricity cannot be cheaply stored, it is necessary that the plant equipment be sufficient to generate the maximum demand at any moment. The number of hours of daily use and their relation to the peak load are important in determining the cost of production. It has been estimated that, under certain conditions, it costs two and one-half times as much to furnish a given unit in one hour as to furnish the same unit in three hours, hence it is important to provide for the long- and short-time users in the schedules.

The type of plant, whether the power is water, steam, or a combination of the two, has to be considered. The actual conditions under which each plant operates must determine the type and details of each schedule.

The four principal types of schedules already considered are used by electric utilities, together with endless modifications and variety of details.

Flat rates are usually based on the number of lights installed or the wattage of the connected load, often with some classification as to use. The simplicity and definiteness of this type of schedule makes it popular with many users, but a meter is necessary as a check for any extended use. The prices vary with each plant, and no comparison of rates is possible. Meter rates are coming into general use, except where the amount of service is definitely known, as in street and sign lighting.

Uniform meter rates are principally used by the small companies. The range of meter rates is very striking. The kilowatt sells at from 25 cents to a fraction of a cent, and the question is often raised whether such a diversity of prices is likely to be permanent. In ten years some maximum rates have been reduced from 20 cents to 8 cents per kw. hr. Block meter rates are in most common use, and are very satisfactory, except when the distinction between long- and short-hour customers is important. Large numbers of blocks have been used, but the tendency is to reduce to two blocks, or three at most. Such schedules encourage larger use, particularly for domestic purposes, as flat irons, toasters, etc., when the secondary rate is made sufficiently low.

EXAMPLES.

10 cents per kw. hr. for first 20 kw. hr. per month.
4 cents per kw. hr. for excess of 20 kw. hr. per month.

or,

10 cents per kw. hr. for first 10 kw. hr. per month.
8 cents per kw. hr. for next 10 kw. hr. per month.
6 cents per kw. hr. for excess of 20 kw. hr. per month.
Minimum bill, 75 cents per month, or $9.00 per year.
Discount 10 per cent. if paid in ten days.

Demand rates are found to be very satisfactory for extended and varied business. The demand is either measured or estimated in kilowatt or horse-power units. The term "Wright Demand Rate" has been applied to a one-charge rate in which the energy charge is on the block system graded on the demand.

EXAMPLE.

8 cents per kw. hr. up to equivalent of first 20 hours' use of maximum demand per month.
6 cents per kw. hr. for equivalent of next 20 hours' use of maximum demand per month.
4 cents per kw. hr. for excess of 40 hours' use of maximum demand per month.

This form may be extended to any number of blocks desired.

The term "Hopkinson Demand Rate" has been applied to a two-charge rate, consisting of a charge based on the capacity of the customer's installation, plus a charge for energy used. Both the demand and the energy charges may be on the block principle.

EXAMPLE.

Demand Charge —
$2.50 per kw. for first 40 kw. of the maximum demand, per month.
2.00 per kw. for excess of 40 kw. of the maximum demand, per month.
Energy Charge —
5 cents per kw. hr. for first 1 000 kw. hr. per month.
3 cents per kw. hr. for next 3 000 kw. hr. per month.
1 cent per kw. hr. for excess of 4 000 kw. hr. per month.

The three-charge rate has been called the "Doherty Rate."

EXAMPLE.

Consumer charge.....$1.00 per month.
Demand charge.....$3.00 per month.
Energy charge.....5 cents per kw. hr.

Another type of rates is based on the product turned out by the electric current furnished.

The maximum meter rate for lighting ranges from 5.5 cents to 25 cents per kw. hr., largely from 8 to 13 cents per kw. hr., and the minimum bill is commonly 50 cents, 75 cents, or $1.00 per month, or from $6 to $12 per year. Of the 138 cities in the United States having a population of 40 000 or over, minimum bills are monthly in 90, yearly in 11, variable in 8, and daily in 1. Twenty-four of these cities have no minimum bills, and 4 are not reported.

Power rates are usually very much lower than lighting rates, and various types of demand rates, block, and uniform meter rates are in use. Among the reasons for lower rates for power

are, that it is usually long-hour and off-peak-load service in large amounts, and ordinary rates would be prohibitive.

Meter rates at present are not comparable on account of the extreme variation in maximum rates, and number and variety of blocks.

Street lighting rates have been termed "good-will rates," but they should be determined according to the principles used in establishing other rates. The lamp-year unit is commonly used, and the range of prices is from $8 to $100 per lamp per year, varying with candle power and locality.

### Gas Rates.

In the gas business, a comparatively large part of the expenses varies with the amount of product, so that any large waste such as is liable to occur in the use of flat-rate schedules would cause a considerable increase in expenses. Hence a meter rate is recognized as the only satisfactory rate for gas, except where consumption is known, as in street lighting. As gas can be stored conveniently, the peak-load factor is not important in gas rates. Uniform meter rates are in common use, but a block system is often used, including lower rates for industrial and domestic uses other than lighting. The increased use of electricity for lighting is tending to single low rates for gas for other purposes. Gas rates range from 75 cents to $1.50 per 1 000 cu. ft., with few exceptions. Minimum gas bills vary with size of meter, ranging mainly from 25 cents to $1.00 per meter per month, or from $3.00 to $12.00 per year.

### Water Rates.

Flat rates still prevail in water utilities, though meter rates are much used. Flat rates are based on the number of rooms, persons, faucets, frontage, and number of stories, assessed valuation or rental value, and meter rates on the daily, monthly, quarterly, or yearly consumption of water. Meter rates are much more just, but the cost of meters, care, reading, liability to freeze in cold climates, liability to leakage, etc., have a strong tendency to limit their use to checking of unusual wastage, unless the water supply is limited.

Meter rates are often uniform, but block rates are used, as in the case of gas, to make lower rates to encourage large use. Two-charge rates may be necessary to meet certain conditions. In a gravity system with unlimited water supply, large amounts may sometimes be furnished at very low rates to the advantage of all concerned. The great diversity of bases of rates and forms of schedules renders any extended comparison of water rates impossible.

The use of water for fire protection is an important feature of water supply, and there is a wide variety of practice in this branch of the business. In a municipally owned plant it is often not taken into account or is regarded as offset by relief from taxes. In some instances, the full cost is charged, which is the proper method of accounting. The problem then is principally one of valuation to determine what proportion of the plant or amount of investment should be assigned to fire protection.

The Wisconsin commission acts upon the principle "that a water company in supplying the two services — fire protection and domestic service — is entitled to have the cost of these services estimated on the same commercial basis." In the Queens County, N. Y., Rate Case, the principle adopted was "that the company was organized primarily for the sale of water to private consumers for a profit, and the city was entitled to get fire protection at its actual cost as an incidental or surplus service." It is very desirable that the principle of proper payment for fire protection be universally adopted. It is important for municipal as well as private plants, as securing a more equitable adjustment of the costs of rendering the entire service. Meter rates range from 5 cents to 35 cents for 1 000 gal., minimum bill $1 to $12 per year, and hydrant rates from $20 to $60 per year, with few exceptions.

### Telephone Rates.

Flat rates are in general use in telephone service. Exchange or base rates usually apply to a radius of from one to two miles or within city or village limits. Residence exchange rates range from $6 to $36 per year, but they are mainly $12, $15, or $18 per year for one or two-party service. Business rates range from $12

to $48 per year, with few exceptions. On rural lines, $12 per year is a common charge, but $15 and $18 per year are being adopted in some localities as necessary in order to maintain proper service. In some cases, stockholders have been allowed reduced rates, but this practice is disapproved by state commissions.

The mileage charge, for service outside the base rate area of the exchange, ranges from 50 cents to $2.50 per year per quarter-mile for different classes of service. Extension bells and sets involve an extra charge ranging from 50 cents to $5 per year.

Toll rates for five-minute messages are applied to zones on the "length of haul" principle. Example, 5 cents for 5 to 10 miles; 10 cents for 10 to 15 miles, etc. In many cases, night service is offered at reduced rates to encourage larger use. Example, — day rate 35 cents, night rate 20 cents. With the necessary improvements in service off the main lines, many of the lower rates are likely to be eliminated.

Measured service for business ranges from 2 cents to 6 cents per message, and block rates are used. Example, — first 600 messages, $24; next 2 400, 3 cents each; excess of 3 000 messages, per year, 2 cents each.

The inequalities in amount of service under flat rates are not as flagrant in residence as in business service, but some limit should be set to the number of messages allowed at a given rate even in residence service. Business service should be largely on the measured basis, as otherwise rates must be well nigh prohibitive for small users. Summer or part-year service presents difficulties which may lead to a two-charge rate involving cost of readiness to serve and of actual service rendered.

### Electric Railway Rates.

Flat rates are in use, and the amount of transportation offered for one fare is variable. The most common charge is 5 cents for a zone varying from 2 to 5 miles, but the range is from 3 cents to 8 cents per fare zone. A free transfer covering a second zone is not uncommon. Commutation tickets at the rate of 21 to 25 for $1, and school tickets at about half regular price, are in use in many localities. Theoretically, a rate system in which the same charge is made for a half-mile as for a five- or ten-mile ride is not

satisfactory, and it is an important question whether these rates should be on a strict mileage basis, as is the case in steam railroad rates.

## Capitalization.

One of the most important duties of a public service commission is the determination of proper capitalization, especially when railroads or utilities are consolidated or a purchase is made and an increased capitalization is asked for. In connection with such transactions, millions of watered stocks have been issued, and sold to a credulous public. This work still goes on in general, but not to any great extent in public-service corporations. It has been — and is to some extent now — claimed by promoters that surplus common stock is the only inducement adequate to secure money to start an enterprise, the idea being to sell the stock and to make it good by large development of the business. Commissions are making a great effort to prevent the issue of any stocks not representing their face value of judicious investment. If we succeed in this, and can reduce the comparatively few cases of over-capitalization to reasonable dimensions, public-service securities will be among the safest investments. In this connection, Corporation Attorney E. F. Jones said, "I believe every public utility — steam roads, electric car lines, light and power companies, gas companies and all others — ought to welcome a valuation of its property by the commission so as to have a stable foundation for future business." (*Street Railway Bulletin*, December, 1916, p. 542.)

The prevention of leases with exorbitant rentals is a kindred duty of the commission. Any over-capitalization or excessive rentals approved by the commission would appear in connection with dividends or operating costs, and would lay undue burdens on the public patronizing the utility. In case of purchase or rental, the commission does not have simply the two parties to the contract in mind, but also has the public, and the test for every case is whether it is for the good of the whole public.

DISCUSSION.

MR. LEONARD METCALF. *Mr. President and Gentlemen,* — I had not thought of speaking upon this question to-day, although it is one with which I have had a good deal to do in the last few years.

I have been immensely interested in the presentation the speaker has given. It seems to me an admirable one, fair alike to the public and to the corporation.

It has been my lot to see something of the working of some of our commissions in a more or less intimate way, the commission of this state, of New York, Indiana, Wisconsin, Colorado, and California, and I have come to be a believer in the work of the commissions, as on the whole distinctly to the best good of the public. That means to the advantage alike of the public and of the corporation. There are certain tendencies, however, observable at the present time, which become apparent when we study the work of the commissions in the last decade. Already we are beginning to get together enough experience in the control of public-utility corporations to indicate that we have made some mistakes. After all, the commissions are but human, and it is not to their discredit at all, indeed, it is distinctly to their credit, that when occasion has demanded they have not hesitated to reverse their earlier findings.

I do want to say one or two words in regard to dangers which I have observed, and to challenge one statement of the author in regard to what constitutes a fair rate of return. One of the most useful developments, I think, of the commission control has been the bringing together, about a single board, of the interested parties, with the commissioners or their representatives, the engineers, acting in a sense as a court of justice. In a number of cases that I have observed myself, it has made for good feeling and it has resulted in a prompt settlement of issues with very much smaller cost than would have been involved by litigation.

Similarly, let the commissioners determine the valuation of a property and the fair gross revenue which the property should be permitted to earn, then go back to the corporation, as on the whole probably most conversant with the local situation, and ask it to establish a rate schedule, along certain lines per-

haps which the commission has laid down, which rate schedule should earn the revenue which the commission has laid down as equitable, reserving, of course, to the commission, the right then to revise the schedule prepared by the utility. One of the greatest dangers comes in the transition from one rate schedule to the other, and in that it has seemed to me that the commissions have not recognized the hazard which they were taking and sometimes have not pursued as conservative a course as they might have done with advantage particularly to themselves. For instance, there have been a couple of cases recently in Indiana in which the rate schedule established by the commission failed to earn the rates which the corporation was entitled to earn according to the views of the commission. Now, in those particular instances it seemed to me that it would have been possible for the commission, either through the establishment of a fairly high minimum meter rate, or through making the transition in two steps, to have safeguarded the interests of the corporation, reserving to itself the right to make further reduction if it was found that the rate schedule as first established yielded more revenue than it thought equitable to the public. It would have saved the commission later embarrassment.

A second question which is causing corporations in certain sections of the country — more particularly in the semi-arid and arid regions of the West — a great deal of anxiety, is the question of the position of the commissions on property which is not actively in the service of the public but which has been purchased with a view to the future needs of the public. It is perfectly clear on a moment's thought that on the question of water rights, for instance, if you fail to acquire water rights reasonably in advance of the needs of the community, by the time these needs develop the rights may have assumed virtual monopoly prices. In other words, they may have been put to other uses, so that if you have to condemn them, the contributory damages may be very heavy. For instance, if those rights had been put to agricultural uses, you would have to condemn not only the water but virtually the properties which utilize the water, to the extent to which those properties would have no value without the water. Therefore this factor has introduced one of hazard to the corporation, and

anything that tends to increase the hazard of the corporation, the uncertainty as to its earnings, is to the disadvantage of the public, because the higher the hazard, the higher the necessary rate of return to command the capital needed for the expansion of the property. This question of course bears directly upon the rate-base, because if any of the property is ruled as out of service, then, if it is otherwise unproductive property for the time being, the actual rate of return upon the *entire* property enjoyed by the owners is less than the *nominal* rate of return allowed by the commission upon that portion which it rules as in the service of the public. In this region, that is not so troublesome a factor as it is farther West, and we have had but few examples that have been burdensome. There is the possibility, however, of difficulty in this direction growing out of the acquisition by corporations of drainage areas tributary to their water supplies, on the theory that if those became too expensive they might accomplish the same ends by filtration. The cost of filtration would, of course, be the limiting value of those properties in certain instances from the point of view of the public. But if it be the position of the commissions at a later date that those lands, acquired in good faith for that purpose, should be ruled out as not necessary to the service, it would have the virtual effect of reducing the return to the corporation and thus either do it an injustice or increase its hazard element and thus do injustice to the public.

Now, the principal issue that I would take with the speaker is in regard to the " rate of return " — not as to what the fair rate of return should be, but as to what he indicated might constitute a fair rate of return. I refer particularly to his reference to the " legal rate of return " as perhaps in many cases constituting a " fair rate of return." So far as my observation goes, I believe it to be true that the legal rate of return would not give the public the service which it desires or to which it is entitled. I believe the legal rate of return in this state is six per cent. I do *not* believe that in the average public-service corporation of this state (I speak particularly of water works because I am most familiar with the water-works field, although I have had something to do with the electrical field, having operated some electrical companies),—I do not feel that a six-per-cent. rate of return upon any

valuation which the commission would be likely to find, would command capital in the long run for the development of such a property. It may be in the case of some older, well-established, large corporations, which have surpluses, that they could for a time command the necessary capital on that basis, but in the long run it is my judgment that they could not do so. And I believe that, if they cannot do so, that is evidence of the fact that you would in effect be confiscating a portion of their property if you applied any such rate to them. Of course it is true that when a corporation is established, — has established its credit so that it can borrow money advantageously upon such security as it can offer, — it can borrow its money at a lower rate than can a concern just going into business and therefore not yet having an established business. I believe it to be true, broadly speaking, of such portions of the country as I have seen, and that covers quite a bit of it, that the rate of return which our public service commissions have been allowing water works and some other utilities, is probably from one-half to one per cent. below such a rate as will command capital in the long run. And I believe it can be said justly of certain localities, notably of Massachusetts, of Boston, that we are seeing a declining service at the present time because of the fact that the rate of return is a little closer than it should be in the best interests of the public. Take as an example that of the Boston Elevated Railway. Its stock sold for years under the jurisdiction of the commission, an excellent commission, at varying prices. I do not know the exact average, but I fancy well over par, perhaps as high as 125. Prices as high as 135 and over have been paid; now it is selling at 70 or less. Why? Because in part, perhaps, of the transfer abuse, because of the rapid increase in the wage scale, and the increase in the demands of the public growing out of the subways and other structures, without increase in the rate of return allowed. Now, the mere fact of the stock selling to-day or in the recent past at a price of 70 or thereabouts, stock for much of which a price well over par was given, seems to me to indicate on its face that the earnings have not been quite adequate. The difference is not great, gentlemen.

As applied to the water-works field, what does it practically mean? It means practically this: Would a family prefer to pay

from one half to two thirds of a cent per day additional in order to enable the corporation to earn one per cent. more per annum upon the cost of its property, in order to have a thoroughly up-to-date service, or would it rather not pay that additional amount and have a service which lags after the demand? Practically what it means, what the limiting of the rate of return to too small an amount means, is that the service lags after the demand instead of anticipating the demand. I don't believe that that is wholesome, that it is desirable from the point of view of the best interests of the public, from the point of view of the development of our cities. It tends, amongst other things, to make it more difficult for the public to get a little further out into the country. It circumscribes our freedom somewhat. And I think it is undoubtedly true that the public is much more interested in having a thoroughly good standard of service than in having a slight reduction in the rates. Of course, time alone can tell whether my belief is justified or not, but it at least will be interesting to watch the developments in the next decade. If my surmise is right, if we are seeing a declining service, the next step, which will come certainly within the next decade, will be that these self-same corporations will be unable to raise the necessary money for extensions upon the basis upon which they have heretofore raised it, even with allowance for the changed conditions growing out of the war; and when you have reached that point, the commissions will be face to face with the question whether they will permit the increased rate of return or whether they will still limit it. If the latter, we shall be unable to command the service, and the only outlet would seem to be public ownership of the plants.

With regard to the question of the rate of return, one word more, and that is this: It is distinctly to the disadvantage of the public to have the rate of return too close, for the added reason that the moment that your rate of return does not furnish a return such as to supply from one and a half to two times the coupon interest upon the bonds it becomes difficult for the corporation to borrow. That, of course, touches upon the basis upon which the money has been raised by the concern, but it means practically that the moment you go below a certain danger point by not permitting a margin of safety in earnings, you penalize

the corporation twice: first, by reducing its rate; second, by prescribing such conditions that it can no longer get money upon such advantageous terms as it was able to do theretofore under a somewhat higher rate. Moreover, it leads directly to litigation, and the commissions cannot fail to take into consideration the very heavy costs attendant upon rate suits and upon the carrying of these suits to the courts, for ultimately the public pays those bills. The capitalist does not lend his money in the long run on the assumption that he will pay the expense of those charges. It may be possible temporarily to say that the costs of those suits shall not be included in the operating expenses of any one year, but in the long run economic conditions will control and those costs will be paid by the public. It is not to the corporation's interest, it is not to the public's interest, to have these suits contested in the courts. And I believe we shall see them settled in increasing measure within the consultation rooms of the commissions, to the advantage alike of the corporation and of the public.

Finally, let me say just one word in regard to the surplus issue of stock, the watered stock to which the speaker has referred. It seems to me that there is a different explanation, and a sound reason, for the issuing of surplus stock, a different explanation from which has been made by the author. Is not the theory, underlying the issue of the surplus stock, that time and expense, expenditure of money or sacrifice of dividends, is generally involved in the building up of the business of public-service corporations? I think that it has been the theory that that development expense, as it has been called technically sometimes, had best be taken care of through the issue of the stock. As that expense is incurred, without return to the owner of the property, it is capitalized in stock issue. It has generally involved expenditures and in later years, when the business has developed to such an extent that it could carry it, in other words, pay a return upon the earlier expenditures, then the stock has developed value and reimbursed the owner by dividend payments upon the debt incurred. That seems to me perfectly legitimate from the public as from the corporate point of view. That, I think, is the proper explanation of the issue of surplus stock. I don't mean to say by that, gentle-

men, that stock has not sometimes been issued without reason and in inordinate amount. Of course we all know that it has been. But, on the other hand, it is true that there is sound and fair reason for issuing stock under such circumstances as I have indicated, or to take care of such intangible rights as water rights, patent rights, or other rights of that kind.

MR. ALLEN HAZEN * (*by letter*). It is always a pleasure to meet old friends in a new field. When "Tute" Worthen was trying to drill "higher" algebra and other mathematical lore into the head of the writer some thirty odd years ago, we little thought that some day his student would be asked to discuss a paper of his on the regulation of rates, a subject not then even thought of. Mathematical training leads to clear thinking, and it is no surprise to the writer to find that Commissioner Worthen has prepared a remarkably concise and clear-cut analysis of this difficult and complex matter.

The writer would suggest in addition or continuation to what Mr. Metcalf has said, that perhaps a little more might be said in regard to rate of return. The writer believes there is one practical and sure final test of rate of return; that is, that it must be sufficient so that as a practical matter all the capital that is necessary will be available to extend the works as needed to afford efficient service.

Efficiency of service is generally much more important to the consumer, as Mr. Metcalf points out, than a small difference in rates. And a five per cent. reduction in rates at a critical point may mean a reduction in the rate of return that, as a practical matter, stops extensions and cripples service.

With reference to the three-charge rate (which logically follows the method referred to by Professor Worthen of classifying costs under three heads) the writer believes that this threefold division probably had its origin in the electric field.

With an electrical equipment there is no storage of the power, and electricity must be generated and carried and distributed to meet the absolute peak-load. Peak-loads in electrical supply are high and irregular, and the cost of furnishing and keeping equipment ready for service to meet these peaks and not other-

* Of Hazen, Whipple & Fuller, Consulting Engineers, New York.

wise needed is a very important part of the whole cost of the service.

With a water-works system, on the other hand, and especially when domestic consumers only are considered, the peak-loads are much less marked in amount and they occur with a remarkable degree of regularity.

In a great many, probably in a majority, of water-works systems, storage of water, connected with the distribution system, is available to help carry these peak-loads. The amount of storage required to cover all of such peaks growing out of regular service is relatively small, and the cost of it is hardly an appreciable element in the whole cost of supplying water. The peak-loads resulting from domestic service are at most only a small fraction of the loads that have to be provided for in supplying fire service. In short, the whole situation of a water-works plant with reference to demand charges is entirely different from that in an electric plant. While it may be admitted that the same principles govern as a practical matter, the writer holds that in a water-works plant the demand charges for domestic consumers are relatively small and may be quite as well distributed into the two remaining classes, with the simplification of the calculations that result therefrom.

This may be less true of the large services through four-inch pipes and larger for railroad and manufacturing uses.

If the consumer charges and the demand charges for domestic takers are considered to be so small that they can be practically ignored, and for the larger services if they are taken at graded amounts which are added to the consumer charges, a series of service charges is reached which in a two-charge rate may be quite as well adapted to distributing the load where it belongs as the more elaborate system of a three-charge rate.

There are, further, some practical limits to the amounts that can be advantageously charged in this way, as the writer recently pointed out in connection with the report of the Committee on Meter Rates.

MR. WORTHEN (*by letter*). I will say a further word on rate of return and common stock, which were touched upon in the discussion.

Issue was taken with the use of the legal rate of interest as a working basis for determining the fair rate of net return on the fair value of the investment, subject to modifications to meet local conditions, and the opinion was expressed that in the long run a six per cent. rate of return will not command the capital necessary for the proper development of public utility business.

It is to be noted that the net return for interest and dividends is in addition to proper allowances for depreciation to safeguard the investment and a proper margin for the successful conduct of the business (see topics Fair Return, Depreciation, Rate of Net Return, and Business Encouragement, in the paper).

Public utility business is of a permanent and necessary character, and should be so controlled that communities shall not be exploited by promoters. I believe that public utility stocks should be regarded as permanent investments, and that the approval of a commission should be evidence that each share of stock stands for its face value of actual investment. Public utility securities, when the business is of considerable magnitude, should be available for trust fund and savings bank investments. With the safeguards of commission supervision to secure integrity of investment, efficient operation, provision for depreciation, and protection from irresponsible competition, I think a six per cent. net return on the investment, with a fair proportion of stock and bonds, will command any reasonable amount of capital in most cases, under present conditions. The facts that large amounts of money are being deposited in savings banks paying only three and one-half per cent. or four per cent., and that comparatively few public utilities are now paying more than six per cent. on the investment even when no restriction has been put upon rates of dividend, are important in this connection.

In the matter of "surplus stock," I applied the term only to stock issued in excess of the actual investment, as a bonus. I think that all "time and expense, expenditures of money, or sacrifice of dividends" should be fully shown in the accounting and provided for either in capitalization or amortization, as seems best to fit the conditions.

The paper is only a preliminary study of the whole field, and it affords an opportunity for infinite extension in many directions.

The section on water rates was left especially brief in view of the exhaustive article by Mr. Wagner, already referred to, and the report and discussions on meter rates found in recent numbers of the JOURNAL of this Association.

The commissions as well as the utilities await with great interest the developments of the second decade of public service regulation.

# THE EXTENSION OF THE WATER DISTRICT IDEA IN MAINE.

BY HARVEY D. EATON, ESQ.

[*Read September 13, 1916.*]

By a constitutional provision adopted by Maine in 1877, cities and towns can incur indebtedness only to the extent of 5 per cent. of their assessed valuation. Prior to that time, very few places in Maine had installed water works. Subsequent to that time, this debt limit was an effectual barrier to the installment of water systems by cities or towns in their municipal capacity. It therefore came to pass that private water companies practically monopolized the business in Maine, Auburn, Lewiston, Hallowell, and Bangor being the only exceptions, though in the country at large the majority of water plants were publicly owned.

In some instances, supplies were pure and service adequate. In other cases, this was far from true. Waterville, Fairfield, Benton, and Winslow were partly and poorly served with water from the Messalonskee Stream, which was the outlet for the sewers of the town of Oakland. For the service rendered, the rates were high. The works were installed in 1887 following a discussion which lasted several years on the advisability of installing a municipal plant. The debt limit and the natural conservatism of the best citizens and leading business men combined to defeat the far-sighted wisdom of those who wanted the people to install, own, and operate a water system.

Both the cost and character of the service became subject to severe criticism within a few years from the time the works were installed. After some years of otherwise fruitless agitation, the idea occurred to me that a new municipality composed substantially of the territory and people served would not be subject to the constitutional debt limit and would also be a convenient political unit for handling the water business. The necessary legislation was procured in 1899, and in the same year the act was adopted by the people of Waterville and the Fairfield Village corporation

which composed the Kennebec Water District. The company made a prolonged resistance to the carrying out of the act, but final decisions were rendered during the year 1902, fully sustaining the district's rights to take over the company's property.

The actual work of condemnation and appraisal was not completed till early in 1904.

Meanwhile, however, the legislative session of 1903 had granted charters to Augusta, to Brunswick and Topsham, to Dover and Foxcroft, and to Gardiner. Procedure became more speedy as the futility of resistance was demonstrated, and these last-named districts were in actual operation almost as soon as the original Kennebec Water District, which was chartered four years earlier. Other charters followed rapidly, until now this form of organization is found in every section of the state from Kittery to Van Buren.

Portland fell into line in 1907. This district is composed of the cities of Portland, Westbrook, and South Portland, and it also has authority to supply water in the adjoining towns of Standish, Windham, Cape Elizabeth, and Scarboro.

But the system is used not alone by large towns and cities with works already established. Small towns like Anson, Bingham, and Strong, which offered no temptation to promoters or capitalists, have organized water districts, constructed works, and are now enjoying the protection and sanitary benefits of water under pressure.

This brief survey of progress arouses many reflections which might easily lead to more discussion than time permits. A few matters may be worth mentioning. The operations of the original Kennebec Water District have been marked with a degree of harmony and also of financial success seldom met with in actual practice. The board of trustees have held seven hundred and ninety-seven meetings since organization in 1899, and never once has the chairman found it necessary to count a vote. No rule requiring unanimous action was ever adopted, but they began at the outset to defer action till all were agreed, and have always followed that practice. The board of five trustees is appointed by three different bodies from three different localities. The term of office is five years, and three of the five first appointed in

1899 have remained in office ever since. Such continuous, united, and successful work as they have accomplished is a tribute to the character and capacity of this board such as few official bodies ever merit.

In regard to the undertaking as a business proposition, the story may be briefly told as follows: Since the district took over the works in 1904, it has doubled the plant, increased the revenue 70 per cent., reduced the rates, and accumulated a surplus and sinking fund of almost fifteen per cent. of the capital cost.

A prime object in the framing of this charter was to remove the choice of officers as far as possible from the ordinary political scramble. It seems to us that the continuity of service and efficiency thus secured amply justify this method, but we observe that the tendency generally is toward choice of trustees by popular election. Of course this is giving every individual a more direct voice in the management of affairs, but we believe it is at the expense of the highest efficiency. Is it worth while? Surely we would not presume to answer.

Obviously, the water district idea is simply public ownership adapted to the peculiar conditions of Maine. It is nearly fifteen years since the Supreme Court pronounced the plan valid and constitutional in all respects. The largest city and some of the smaller towns have adopted it. Yet an actual majority of all the water plants in Maine are still in private hands. From this statement alone one might be in doubt as to whether the movement was an actual success. But as we note the success, efficiency, and economy of operation, together with the general satisfaction of consumers, and make comparison with communities where private plants still subsist, one cannot escape the conviction that the water district idea was a real blessing to Maine.

# THE WATER SUPPLY OF PORTLAND, MAINE.

BY DAVID E. MOULTON, ESQ.

[*Read September 13, 1916.*]

The Portland Water District is one of those peculiar, quasi-municipal corporations that our friend Mr. Eaton conceived years ago. The expressed purpose, and supposedly sole purpose, of a water district, you know, is to furnish water. The real, underlying purpose, however, is to get around the debt limit and enable municipalities to buy water works. The Portland Water District consists of Portland and South Portland, — that part of Portland that is exclusive of the islands in the bay. It supplies water to those cities, and the neighboring city of Westbrook, and six or seven other adjoining towns.

The system reaches from Sebago Lake, some fifteen miles, to the city of Portland, thence along the coast to the east to Falmouth and Cumberland, some seven miles, and to the west, out through Scarboro, some ten miles, making a system in all of rising 250 miles of mains and distribution pipe, supplying a population of practically 85 000 in the territory, of which probably 75 000 are water takers, and having about 15 000 services.

The principal part of our water system is very ancient; in fact, I think it can safely be said to be as old as any city in the world. I do not refer to the ancient cement mains which we have here, although there were engineers found at our hearing who were willing to vouch for their super-excellence and their perpetual life, and I do not know but events are showing that they were right. I refer to the great natural reservoir or settling basin which we have at Sebago Lake.

This lake is one of the largest bodies of pure water known in the world. The lake is some 265 or 270 ft. above mean tide in Portland Harbor, only fifteen miles from the city, and in this reservoir alone there is a water surface of over fifty square miles tributary to the lake, and there are forty-seven other lakes and ponds with an average area of about a square mile each. To be

exact, there are forty-two square miles of water surface in the other lakes, which are all tributary to Sebago Lake, so that there are ninety-two square miles of water surface. Sebago Lake in some places is 360 ft. deep, or 100 ft. deeper than mean tide in Portland Harbor, and there is in the lake eight times as much water as flows from it in a single year. In other words, if it were possible to drain the lake, the Presumpscot River could not only supply the mills on the river, but the water district could use all the water it wants for eight years. That supply would continue uninterrupted if not a drop ran into the lake. It is estimated that less than three inches of the surface water is required for a year's supply to the city of Portland, and there is running off every day from the lake at least 400 000 000 gal., practically enough to supply the city of New York.

All this was ours to start with, and our problem has been not so much to create as to preserve; principally, of course, to preserve the purity of the water, which, in its natural state, is unexcelled for drinking purposes. The upper part of the lake is in a hilly, wooded section; the lower part, cleared more or less; and the water district main starts from the lower bay, about a mile and a half or two miles across. The water district has acquired, for the protection of the water supply, the greater part of Indian Island, the land down to the railroad station, ultimately intending to control the whole of the land upon the lower bay. We have an understanding with the Maine Central Railroad that no structures shall be permitted on their land for the habitation of man, and we have an understanding with the owners of the sawmills which are in operation that as soon as the timber is cut off, the land occupied by them will come to the water district, so that we are practically protected as far as the ownership of land at the lower bay is concerned.

Near our intake house there is a conduit which runs through a rocky rim which holds the waters of the lake. This conduit is about a mile long and leads to a reservoir at lake level. In some places it is 30 ft. below the surface and was blasted through a solid ledge, tunneled through in some instances.

In reading the story of the construction of the conduit, back in 1868 or 1869, I was interested to see that they announced, as a

great event, the fact that a man from New York had been engaged to come and blast with nitroglycerine, something that was practically unknown here at that time, and they prophesied great progress from the new explosive.

To protect this land which the district has acquired around the lake, a wire fence has been built, and all of the land has been fenced to protect it from picnic parties and trespassers. At our intake house, there is a 48-in. cast-iron pipe running 500 ft. out into the lake.

The Sebago basin is a reservoir at lake level at the mouth of the conduit, the water coming down through the conduit, going into the settling basin, as it is called, and then back through the gatehouse to the several mains of the city. In the gatehouse, we have a plant for the hypochlorite treatment of the water. I suppose these plants are familiar to you. There are two concrete tanks in which the mixture is made, and there are automatic devices which lead to the 48-in. mains through which all the water comes before it is distributed to the several mains leading to the city, and by a meter the flow is regulated in accordance with the consumption of the city.

One of the problems that we had was a small brook that ran down through the village of Lake Sebago, near the station. This brook practically took the entire drainage of the village, and it emptied into the lake only about a mile and a half from our intake. The tests of the water invariably showed colon, and all sorts of schemes were devised to protect this brook. There was an old gristmill near the lake, and it was thought to condemn that, but none of these things seemed to be sure to correct the evil, and so finally we decided to construct a plant to sterilize the waters of this stream before it got to the lake. We built on land of the Maine Central Railroad, two years ago, a second hypochlorite plant, and here we treat the waters of the stream. It might be interesting for you to learn the result of this treatment. I think the lowest test showed some 3 000 bacteria, and the best results that we have ever had with the raw water showed that the water was productive of coli in three out of five tests. After treatment, this water will show a reduction of 99 per cent. of the bacteria, and I think there has never been any test showing coli

in the water after it had been treated; so we have practically sterilized the waters of this brook.

There is another little brook near our intake. This is on the shore of the lake, within a quarter of a mile of the intake. There is a small natural watercourse that gets the flowage and drainage from the street. Naturally, that picks up more or less coli in the spring, that being the only time there is water in the stream. We made tests, and found we were getting coli, so, while the brook was hardly large enough to warrant a permanent plant, at an expense of some forty or fifty dollars we built a little temporary plant, and our caretaker at the lake goes down there and mixes that up, and, by a little attention two or three times during the day, he arranges that little plant so that it sterilizes the waters of that brook. It is a very simple operation. We simply use it when the water is running, but we feel that we are getting splendid results from that little outfit.

The Bramhall Reservoir was built at the time of the original construction of the work in 1868, and, along in 1882, one morning it broke out. There was a sort of wall or parapet of stone built around the top of the reservoir, and the water worked along between the stone and the clay puddle, and by frost kept lifting it up, until finally it worked out through the corner, the water being carried in those days within several inches of the top of the wall. So the wall was broken through, but afterwards when this was rebuilt, the parapet was taken off and the water line lowered several feet, reducing the capacity several million gallons, but it has been in use ever since, and is in use to-day, simply as a storage reservoir.

The water system in the city, while built originally for a single high-pressure system, was divided in later years, for convenience, between a high and a low service, and the two reservoirs are now on the low service. Before the new main was built, a standpipe of some 600 000 gal. capacity was built right near the other reservoir on Munjoy Hill, the other reservoir having a capacity of about 20 000 000 gal. This was built to help out the high service, filling up in the night time, and gradually being emptied during the higher output during the day. It was located right beside the Munjoy Reservoir, so the overflow, if there was any during the night, could discharge into the Munjoy Reservoir.

The Munjoy Reservoir also had to pass through its trial, not by fire, but rather by water, and we had quite a calamity there. There was a break in the corner of the reservoir, and perhaps some of you will remember about it. It carried away one or two buildings, and resulted in the loss of one or two lives.

The trouble was found to be in the overflow pipe. This pipe was originally built practically through the center of the embankment, the water found its way alongside the pipe, and finally got out and carried away the fill. It was reconstructed so that the overflow is practically along the surface, and there has been no trouble with it since.

We have a shop on Kennebec Street which was formerly used for testing meters, and which was a legacy from the old water-works company. This building formerly contained our meter department and the bacteriological laboratory, but it is now simply used for a shop and storeroom. We have found it necessary to meet the modern conditions by automobiles, and we have also found that they contribute their share to the high cost of living.

In our laboratory, we test fifteen samples of water each day during the year, and we have been doing this for about three years. While we have found nothing to alarm us in the condition of the water, we treat it, as I have before mentioned, with hypochlorite as a precautionary measure, to remove any chance pollution.

Some three years ago we built a 42-in. cast-iron main to the lake. At the time of our taking over the water works, some eight or nine years ago, it was developed that the capacity of our mains was practically exhausted by the domestic supply, and that we had no fire reserve, so the district was forced to start out and build a new main, and a 42-in. main was constructed from the lake to the city. Practically the whole of the work of digging the trenches was done by a contractor with a digging machine, with very good results on most of the territory. Our other mains follow the highway, but the new one goes practically all of the way over an altogether different route, so that in case of an accident to one, the other will not be involved.

It might be of interest to you water-works men to have some report on our cement mains. The original main was built in 1868,

or started in 1868, and the water turned on in 1870, I believe. This was a 20-in. wrought-iron pipe, riveted cold, with a single row of rivets, and lined with cement. I believe the method of doing that was to stand the shell on end, and pour in a certain amount of liquid cement, and then lower a heated cone in it so it would leave the cement the necessary thickness on the inside, and a coating was put on as it was laid, afterwards. This pipe at the hearing was stated to have a margin of safety of only 2: 2.5 under the pressure it was then carrying. It was quite a question as to the value of these mains. The 24-in. main was built in 1874, I think; several years later, anyway, but of standard riveting. These cement mains have been in use since that time, and while we have no record of the cost of maintenance of these mains previous to taking them over by the district, they have cost us an average of less than $200 a year for each main; that is, the breaks and leaks on them average less than $400 a year for the eight or nine years we have had charge of them. Of course, their carrying capacity is the same now as it was originally. It does seem, for country mains, where they are not likely to be disturbed by the surface work, that they are good for a great many years yet. In cases where we dig to the mains, the cement where it has been recently broken off shows the metal to be bright and clear, and practically as strong as ever; so nobody can estimate how long those mains will last.

At the time the water works was taken over by the water district, a number of the employees came with them, and all of us who have been connected with the district in recent years feel that we are under great obligations to those employees who came to us from the old water company. Many of them had been in the employ of the old company for years, and last year our general manager, Mr. Graham, conceived the idea of having gatherings of these employees to discuss local problems. So we have an organization known as the Portland Water Meeters. They meet once in two weeks during the winter, and some problems are presented to them as to what should be done in case of fire or breaks at certain places. Papers are assigned, and afterwards there is a general discussion, and we have found that the men take a great deal of interest in these meetings and that great good is coming

from them. One of these employees who came to us from the old water company had been with them a great many years, and he could not be prevailed upon to take a vacation until they told him he could use it traveling around looking over the cement mains. So he takes his vacation traveling around and looking over the old mains. It is his special pride to look after them and take care of them, and perhaps that is why they are looking so well. These are types of the good old-fashioned employee, before the days of labor unions, who were willing to stand on their own records for the work that they did. Unfortunately, that type is growing fewer every year, but we do appreciate them while we have them.

I presume a great many of you had the pleasure of meeting the late Millard F. Hicks, the first treasurer of the Portland Water District. He was a member of your Association. I am sure, if you knew him, you loved him, because the pleasure of his acquaintance was a privilege to anybody who knew him. At the time the question of municipal ownership came up, the fact that Millard F. Hicks was the treasurer of this organization gave it the unqualified approval and confidence of every man in the city, because his integrity was beyond question, and we are indebted to him a great deal for the success which the district has had.

The district has been running some seven or eight years, and during that time there has been a steady but not phenomenal growth. The number of services has increased about 20 per cent., and the franchise account, represented entirely, of course, by the construction, has increased from $4 000 000 to $6 000 000, and there has been a steady reduction in water rates, and this in spite of the fact that the district is supplying water to the city of Portland for fire and municipal purposes without any charge whatever.

There is in this connection an interesting feature which is now before us, which has often been before your Association, and that is the question of payments for private fire services. A short time ago that question was raised by the Portland Water District by a petition against itself, in which the district made the claim that the present system of a minimum charge for water was unfair; that is, according to our rules, if a person took a hundred dollars' worth of water, for instance, he, as a perquisite of that amount of

water, should be allowed a private sprinkler system or hydrant service without payment. We made the claim that was not just; it was unfair; it was discrimination, and it was illegal, but that it was forced on us because the claim was made to us and we could not deny it. In our petition to the Public Utilities Commission, these facts were set forth, and the commission has recently filed an order upholding the position of the trustees, stating that the system of charging for private service was unjustly discriminatory and void, and ordering the trustees to file a new schedule of charges, which should be independent of and additional to the charges regularly made for the use of water. That schedule has not yet been filed, but I thought it might be of interest to you, who have discussed this matter so often, to know that the Public Utilities Commission of the State of Maine, at least, has taken the position that the present system is not fair.

While the water district has furnished to the city of Portland water to the extent which at our regular charges would be about $40 000 a year, it has still been enabled to reduce water rates, has increased the investment in the plant, largely represented by the new main, and has also accumulated a sinking fund, so that we feel we have justified our existence.

Perhaps the man who has done most to build up the Portland Water District is Uncle Eben Dyer. Many of you knew him. He was bound up in his work, and a genius in his line.

### Discussion.

President Sullivan. There was one thing in Mr. Moulton's paper that struck me, and that was his commendation of the old employees, and the splendid record his company kept of them, with photographs. We do not, in many cases, treat our old employees as they should be treated, and I am very glad to find out that the Portland Water District is going to appreciate and carry in fond remembrance the old men who did the work, before the labor unions got to grade all men alike. There was no grading in the old days. A man was willing to go out all day, night, Sunday, or holiday; would not take a vacation, interested and loyal, and every water works in the country, the older water works particularly, had these men, a type that is fast disappearing.

# THE WATER SUPPLY OF MADISON, ANSON, AND EMBDEN, MAINE.

BY LEWIS L. WADSWORTH, ASSOC. MEM. A. S. C. E., PRESIDENT OF THE HANSCOM CONSTRUCTION COMPANY, BOSTON, MASS.

[*Read September 13, 1916.*]

Madison, Anson, and Embden lie in the valleys of the Kennebec and Carrabassett rivers. The towns are progressive and are devoted mainly to manufacturing and agriculture. Power is supplied by large water privileges highly developed, and the agricultural products are as fine as any raised in the state of Maine.

The first organized effort to secure a system for the villages of North Anson and Anson dates back to the winter of 1912, when some prominent citizens secured a charter to form a private water company, to supply the territory with water for domestic use and fire protection.

Surveys were made and a proposition presented to a well-attended town meeting. The citizens were asked to pay the water company an annual hydrant rental of $2 500 for up-to-date fire protection. The proposition was rejected with almost no discussion by the voters, the sense of the meeting being, that when the town was ready for water supply it would install and own its own plant.

The indications for revenue from this territory were good enough to interest private capital, for, in addition to the income from the villages of Anson and North Anson, an additional revenue of $2 500 could probably be obtained from the Madison Water Company. This company operated in adjacent territory and takes its supply from the Kennebec River, which was badly polluted and to-day is condemned.

Each succeeding year the question of water supply was agitated by the citizens. During the winter of 1914, Anson secured a water district charter from the legislature, and in the following spring they accepted the act and voted to build a plant.

Contracts for supplying all material and doing all the construc-

tion were let to the Hanscom Construction Company. They are three contracts in number, and aggregate $165 000.

The plant was started in the spring of 1916, is now 60 per cent. completed, and will be finished before cold weather this fall (1916).

In addition to the revenue which Anson would receive from the takers on their own line, the Madison Water Company, not wishing to go to the expense of securing a new supply, offered to enter into a long-time contract for water to meet their requirements. They were willing to pay $2 500 yearly for approximately 150 000 gal. per day, and offered their reservoir to Anson to take care of excessive demands, as in the event of fires.

As Anson's new system was to be a gravity supply, and large pipes were to be used to give fire protection, they could also supply Madison with water without much, if any, additional cost. The return offered for this service by the Madison Water Company was nearly two thirds of the interest charges on the cost of Anson's trunk line, which had to be built at all events.

The psychological moment then had arrived. A number of the citizens of Anson were quick to grasp the situation, and called a meeting to ratify the contract in hand with the Madison Water Company, to supply that town with water for a long term of years.

If private interests had had the situation to handle, the opportunity would have been seized, but, as is often the case in public affairs, opinions were divided and the project was held up mainly on two issues. The first, that more revenue should be paid by the Madison Water Company, and second, that the pipes were too small. On the first issue the Madison Water Company refused to do more; on the second issue, the leader supporting the claim of small pipes used as his principal argument a two-foot rule on which he held his thumb on the 10-in. mark and left the voters to decide whether or not pipe of that size could supply the water.

As the contentions were sincere, the trustees of the Anson Water District asked for the opinion of Engineer William S. Johnson, of Boston, who looked over the layout and advised that the sizes of the pipes were adequate. He also recommended that the portion of the gravity supply line starting at the pond and running to North Anson, and on which there would be only a few services, be built of wood in place of cast iron. This would effect a consider-

able saving on costs, and the carrying capacity would not decrease during the life of the pipe, as in the case of cast-iron pipe, due to incrustation.

During these weeks of debate and uncertainty in Anson, the citizens in Madison realized that the yearly sum to be paid for water would come direct from their pockets. They acted quickly, stepped in, purchased their system, and refused to enter into any agreement whereby they were to pay to Anson yearly the sum previously decided upon.

The situation then was this: both towns wanted a new water supply and they both wished to work together. They were agreed on a common source, Hancock Pond; neither cared to lay in their own supply line alone, thus duplicating twelve miles of pipe, and indeed we doubt very much if the Utilities Commission of Maine would have allowed this.

Out of this situation developed an idea which to the writer is somewhat new. The trustees knew they could combine their towns and form one water district, and that it had been done successfully in a number of cities in Maine. This, however, was not desired, as under that arrangement one board would have the direction of the water affairs of both towns, and the smaller town would rightfully be in the minority on the board.

The problem was worked out by entering into an agreement whereby both towns were to have joint ownership in the main feed line only. These affairs are handled by both boards of trustees acting as one. Affairs pertaining to their distribution systems, however, are handled differently. Each district has its own board of trustees, collects its own revenue, and decides where to make its own extensions; each makes its own rates or raises money whenever it is needed.

When the citizens of the Madison Water District purchased their system, they decided to make changes to secure high-pressure fire protection, and at a joint meeting of the boards it was agreed, inasmuch as the Madison people were mostly benefited by this change, that they should stand sixty per cent. and Anson forty per cent. of the cost of the jointly owned pipe line.

The system is a gravity system. From Hancock Pond, the source of supply, to North Anson, a distance of seven miles, we are

using a 16-in. wood stave pipe. This wood stave pipe ends just before the distribution system of North Anson begins. There are only a few services taken off this wood stave pipe. From North Anson to Anson there is a 14-in. cast-iron pipe, and a distribution system is installed, as well as at North Anson. The idea of this line is not only to take care of the two villages of Anson and North Anson but also to furnish Madison a new supply. The old Madison reservoir is considerably below the new source, and therefore can be reached by Hancock Pond pressure. This reservoir will not be used, but so connected that, in the case of any trouble with the line, it can be called on as a secondary supply.

W. H. Sawyer, of Lewiston, was engaged as engineer for both districts, and A. F. McAlary took charge as resident engineer.

When the work started, this spring, it was found that conditions governing material and labor were greatly changed since the previous fall, at which time the contract was let. Embargoes on railroads existed, and labor was scarce, high priced, and poor.

It has been said that necessity is the mother of invention, and because of these conditions we are doing eighty per cent. of our digging with a twenty-ton gasoline-driven trenching machine, and filling the trenches with a gasoline-driven traction back filler. The excavator makes rapid progress in clay or gravel ground free from bowlders and ledge. When the latter is encountered, we excavate down to the rock and pass over, resuming full depth when earth is reached again. In hard clay-gravel, a stone the size of the fist will stop its digging, neither can it be economically used in any soil full of fair-sized bowlders. In a few soft, sandy spots, it has pulled out stones as large as a football.

The back filler is sold with the recommendation that only one man be used to operate the machine. We, however, use two additional men on the spoil bank, to set the scraper into the earth at the time the operator draws it toward him. We also find it necessary to clean up with handle shovelers. Progress made by this back filler has always been in excess of any trench we could dig for it to fill when it was not out of commission,—due to breakdowns,—which was often.

At the upper end of the pipe line, close to Hancock Pond, two miles of the wood pipe is laid in a trench four feet deep, through

woods and in ground consisting of nested bowlders. Here we have done away with labor again and resorted to dynamite to do the digging. Half-pound sticks of 20 per cent. and 40 per cent. nitroglycerine are dropped into holes, made with a steel bar, on approximately 3 ft. centers, close to or under the bowlders, and detonated 40 holes at a time. In ground carrying a network of roots, many are broken off and the rest left free from soil so they could be easily and quickly cut with an ax. In all cases, any hard soil in the bottom of the trench was softened up for the shovel by this process. Bowlders containing two or three yards have been shattered without drilling, with 75 per cent. dynamite, by the usual methods of mud capping.

We have found this cheaper and quicker than baring out and hoisting with chain falls, and will continue this method in similar ground even when labor returns to normal conditions.

Before we placed our order for wood pipe, we found conditions not as satisfactory as in the cast-iron pipe industry. Standard specifications for Canadian pine stave pipe call for a class of lumber that is hard to get and rapidly getting scarcer. It is impossible to tell if a knot passes entirely through the stave, as the outside is covered with $\frac{1}{4}$ in. of asphaltic material as well as continuous steel bands. Standard specifications also prohibit large knots, yet they get a bearing against the steel bands and therefore cannot blow out. Specifications call for the steel used in banding to have an ultimate strength of 60 000 lb. to the square inch. On all tests of our pipe, the steel exceeded this amount. The bands are spaced on the pipe on centers to follow the pressure occasioned by the changing contours of the ground, and in this work a factor of safety of four is used, based on the elastic limit of the steel bands as 16 000 lb. per square inch. This is not the practice of some of the manufacturers, as their spacing is based on a factor of four, using the ultimate strength of the steel bands.

It seems wise to the writer to have this extra factor of safety in the bands, for, if it be granted that the wood stave saturated throughout with water lasts indefinitely, then the life of the pipe is the life of the steel bands and they are subjected to continuous moisture.

When relief valves, air valves, or blow-offs are used, the wood

pipe is driven into a cast-iron tee with machined sockets, and the valve is attached to the tee, as is customary in cast-iron pipe practice.

No wood specials were used except when laying to vertical or horizontal curves; then short pieces of pipe are laid which are built to a slight curvature. All wood stave pipe used on the work is of the Michigan manufacture.

If the districts were to let the work under the present prices, instead of those which prevailed last fall, the cost of the material alone would exceed an advance of $22 500.

## Discussion.

Mr. M. Knowles.* Mr. Wadsworth says that the wood pipe, under the conditions in which he laid it in the first section, was considered to be the proper thing to lay, and that the specifications under which it was laid, and the requirements, made it necessary to go even a little further than the wood-pipe people themselves thought or suggested to be wise. It would perhaps interest us to know why he stopped at North Anson, and did not continue for the remainder of the supply line, and, if it was wise to use it for the supply line, why could it not have been used for the street lines, and save still further expense?

Mr. Wadsworth relates that it was cheaper to use the trench machine rather than shovels in ground where there was quicksand, even though large quantities were taken out. Will he please tell us something about the slope at which the ground came in, something about the excessive excavation that was encountered. Would it have been at all cheaper, or has he tried to use freezing devices ahead of the machine, to prevent any caving in at all?

Mr. Wadsworth. In regard to freezing devices, the amount of money received for doing this shallow trenching was somewhere around 18 or 20 cents a foot. I have never had any experience with freezing devices, but I think perhaps, inasmuch as we were paid so little, we could not afford to install them. If we have got the work to do, it does not make any difference what we are paid for it, we have to go to the expense of doing it. Where we

* Consulting Engineer, Pittsburg, Pa.

were paid something like 20 cents a foot for the excavation, we succeeded in removing the quicksand to a grade of about four feet, with the machine. It kept caving in; each time it caved in, naturally the banks were a little wider. As we widened out about eight feet, perhaps the banks were two feet high; and then it was a gradual slope to the trench where we laid the pipe. That takes care of four feet of depth. So for the other two feet, we would jump in with shovels, put the pipe right in, and run the joints immediately, thus keeping ahead of the flowing sand.

In regard to using wood pipe on the distribution system, that was considered, and the reason it wasn't used was because of installing the services. The service connections are made by screwing a corporation cock into the wood, and the only thing we have to rely on for that connection with the wood is the slight thread on the corporation. As a matter of fact, where we have made any services, we have not used the corporation screwed into the wood. We have bored a hole through the wood, installed a brass nipple with nuts and washers inside and out, and in that way avoided construction involving the use of a wood thread. I don't know as that has been tried out anywhere else.

The question why we didn't use wood pipe on all the system is a pertinent one. Some of the trustees asked, if we could use it on part of the feed line, why we didn't use it right through. The real reason was this: They had so much money to spend, and while they all recognized that the Ford is a good car, they would much prefer to have a Packard, if they had the money. So the cast-iron line from North Anson to Madison is considered a Packard line, and the wood stave from North Anson to the pond is the Ford line.

MR. HAWLEY. I would like to ask Mr. Wadsworth if any test was made on this wooden line for leaking, and if so, what was the result.

MR. WADSWORTH. There has been no test made yet, because, while the line is almost completed, we have not turned the water into it. I can say, though, we have known of several lines that have been properly put together that have actually leaked less than a cast-iron line with lead joints. I speak of lead joints, because there you get the labor of calking, which makes them

tight. We know of joints which have been made with other material, cheaper and tighter than lead.

I don't want you to get the idea that we don't value wood pipe. I believe, with the present price of iron, wood pipe is something that is coming strong. If you were to figure the difference of the cost of our 16-in. main, between wood and iron and the interest on it for twenty-five years (and this line will surely last that long), the amount saved will pay for a new wood line purchased and laid. If these towns had been towns of large valuation, I imagine they would have put in cast-iron pipe, right through to Hancock Pond.

Our line is built of Canadian pine. The specifications called for something which we do not really expect to get; they called for a grade of pine the knots of which do not go way through; and no knots which are large. We have some large knots in it, and we have some small ones, but, as I said in my paper, we can't tell whether they go through, because there is an asphalt coating of one-quarter inch, which covers the knot, and a great many times the steel band will come outside the knot.

We expected trouble from allowing the asphaltic coating to be exposed to the sun for a month before the pipe was laid. We found, however, from the manufacturers, that the Standard Oil Company made a coating that is so soft at first you have to roll it in sawdust, but the heat of the sun, because of the peculiar properties of the coating, does not make it any softer. You can buy pipe and leave it around, as far as the coating goes, and you need not be afraid it will run and become thin on top. Of course, if you leave a wood pipe exposed very much, the staves will shrink. That is the danger of letting it lie around, as you have to, oftentimes, four or five weeks before laying it in the trench.

MR. MCKENZIE. In regard to the trench machine, we had some experience in 1911 in laying new main, and it was not an entire success with us. I think in a ground which is plain, or free from roots and stones, it would work very nicely, but in most of our New England towns which are situated a good deal as we are, with unforeseen roots and stones continually slowing the machine, I think the contractor would have done the work cheaper with labor at the price it was at that time, without the machine.

MR. FULLER. I would like to ask what the expectation is in

regard to the loss of head from friction in this wooden pipe, as compared with cast-iron pipe.

MR. WADSWORTH. I can't answer that question from any experiments, but I believe that the Williams and Hazen hydraulic tables state that wood pipe has a greater loss, due to friction, than new cast-iron pipe.

The dealers (and they seem to be sincere in their claim) use the argument that after the wood pipe has been used a little while, it becomes coated over inside with some sort of a slime, which acts as a lubricant to the flow of the water. In any designs or investigations our office has made, we have always used the same coefficient for wood pipe as for cast-iron pipe.

# THE FIRST SLOW SAND FILTER IN THE STATE OF MAINE.

BY HENRY RICHARDS, TRUSTEE OF THE GARDINER WATER DISTRICT.

[*Read January 10, 1917.*]

My appearance as understudy to Mr. Arthur T. Safford, in writing this paper, is due to his suggestion that even engineers sometimes get tired of talking shop, and therefore may be glad to hear occasionally from an outsider.

Whether Mr. Safford is right in his idea, or otherwise, I hardly think that such an everyday affair as the building of a slow sand filter for a little town in Maine could have much technical or professional interest for this Association. But the other side of the matter — the human, social, and, if you like, the political side — is clearly of interest to anybody, anywhere; because it concerns the human relations which underlie, and, in the end, must govern everything we do.

Looking at it in this way, I used the title, " The First Slow Sand Filter in the State of Maine," not because our little filter in Gardiner can lay claim to any historic interest or value from being the first of the kind in the state, but simply because the fact of being first, in such a state as ours, carries with it a whole train of interesting difficulties. For we are intensely individualistic in the state of Maine. We don't like to be told how to do anything — least of all to be told by anybody from Massachusetts, because we can never forget the time when we were the biggest, and (so we thought) most important part of the Province of Massachusetts Bay and the later Commonwealth of Massachusetts. Maine would claim the North Pole by grace of its discovery by Admiral Peary. She would call herself the mother of modern milling by virtue of the Washburn Mills at Minneapolis. And she would assert her determining influence in modern methods of warfare through the work of Sir Hiram Maxim. Wherever things are doing, anywhere throughout the world, you will find a Maine man near the center of activity; and if the good old state fancies her-

self a little because of the triumphs of her sons, it is hard y to be wondered at.

These triumphs have been achieved by men who have gone out from the state, as they have been doing in a steady stream since the first exodus to California in '49. The exodus still goes on. Young men from our high schools go out and win name and fame for themselves abroad, or in our own West; but how about those who are left at home? You cannot draw off your best blood, generation after generation, without affecting the parent stock. Maine is a backward state, paradoxical as it may sound, precisely because of the vigor which has made her a reservoir of ability to be drawn on so freely by others. There is still plenty of vigor left! We are proud of young Holcombe, who left the state years ago, and is, we are told, a hydraulic engineer of international reputation; but we all know that his uncle, old Deacon Holcombe, out at the crossroads, has been the leading millwright of the neighborhood for forty years, and is a far smarter man than his nephew, whose lively career at the high school is still remembered.

There are great corporations in the state, which, of course, do modern work by modern methods, and obtain the best expert advice wherever it can be found. But, when an engineer is called upon to develop a public utility down in Maine, he will at once be up against Deacon Holcombe and his kind, — men of great native ability and much acquired shrewdness, but with no scientific training or knowledge. And the deacon and his kind, we must always remember, carry the votes. Human nature may be much the same the world over, but in a small, backward, and highly individualized community, and when undertaking an operation — like a filter plant — which is the concern of everybody, the engineer must not expect to be *persona grata* because of his retainer, or be surprised to find himself suspected at every turn. From his clothes to his professional fee, from his methods to the scientific data on which they are founded, everything will be questioned; nothing will be taken for granted or accepted as proved. His plans may be regarded with some respect as things not fully comprehended, but the respect will be tempered by a firm conviction that the town surveyor could make a set of plans for twenty-five dollars that would look every bit as good. Why

should a stranger be paid fifty dollars a day when " all there is to it " is a lot of concrete, and everybody knows that the local mason, who does the best concrete work in the county, can be had for five dollars? If the engineer is " on the job " and is paid *per diem*, the cost runs up, and that will never do. But if he delegates his authority to a resident assistant, he is criticized for not being on the job.

The resident assistant is a plain mark for the rapid-fire batteries of criticism. Working from a close specification, watching his unit costs, and judging by results, his way of doing things violates every precedent of local usage and the accepted dictates of common sense. He arranges his machinery, balances his crew, and knows what he is doing, but the picturesque element of bossing is lacking, and every practical man who drops in to see how things are going, bombards him with questions and advice until his only refuge is in silence.

To add to the interesting difficulties to be met in building such a filter as the one under consideration, in a little place like Gardiner, and especially when it is the first to be built within the knowledge of the beneficiaries, there are the really intelligent but uninformed people, who know that no filter is needed because the public water supply has always been the best in the state; those who consider it all nonsense because they can buy a perfectly efficient filter for fifty cents at the plumber's, and those who are sure that bacteria are an invention of the doctors to increase their practice. And when at last the work is done, and the trustees turn on the water to flush out the system, they are met by an excited citizen who has just seen a barrel full of fish that were taken out of the pipes.

As a wise observer said, " The trouble with our people is that they have never been where work is done, and so they don't know how it should be done." The native ability of keen, alert, but untrained minds multiplies the problems, but adds to the interest of such work as this.

And politics? The state of Maine, you know, is a storage reservoir of politics, piped off into every community. I doubt whether Gardiner could ever have had its filter plant, if it had not first adopted commission government. It is the only town in

the state under commission government, and is the first one to have a slow sand filter. The connection, I am convinced, is not fortuitous, but is direct cause and effect. For we are a fighting town, and under commission government the power of the two-party system to choke all progressive endeavor is much weakened, and our struggles have borne fruit.

I have sketched in the human setting of the undertaking at Gardiner, thus briefly and roughly, not only for its intrinsic interest, but as an example and a warning to young engineers, who are never taught in the schools that the human element in any engineering work is more than half the battle, and are often sadly puzzled when they first encounter it. With this introduction I now go on to a more particular description of the conditions and plant at Gardiner.

Gardiner lies on the west bank of the Kennebec River, about six miles below Augusta, and at the mouth of the Cobbosseecontee stream, which has a fall of about one hundred and thirty feet in the last mile of its run to the Kennebec. This situation determined, first, the gathering of Indians, who came there to catch and cure their salmon; and, later, the settlement of white men, who came to trade with the Indians, and remained to build mills and found a city.

The Cobbosseecontee basin has a drainage area of about two hundred square miles, with a storage area of twenty-one square miles in fifteen ponds. There are eight dams (latterly reduced to seven) in the last mile of the run of the stream to the Kennebec, dam No. 8, the upper dam, being the storage or reservoir dam for regulating the supply of water to the mills below.

The Gardiner Water Company, chartered to supply the city of Gardiner and the adjoining towns of Randolph and Farmingdale with water for municipal and domestic purposes, built the present works in 1885, with a pumping station on dam No. 8, and an open reservoir of about two million gallons capacity on a hill a third of a mile from the pumping station, connected with the piping system by a single main. The intake is from the forebay of dam No. 8, and the pumps are driven by the power developed on that dam.

The Gardiner Water Company went through a number of stages of absorption, enlargement, and reorganization, until it emerged

finally as the Maine Water Company, owning and operating plants in many parts of the state. In 1902, the citizens of Gardiner voted to buy the works, and a charter was granted by the legislature to the Gardiner Water District, under which they were empowered to take over the Gardiner plant and franchises of the Maine Water Company at a price to be determined by a court constituted to hear the case. This was done in 1903, and three trustees were elected by the city government. These trustees found themselves facing a serious situation. Like most of the watersheds in Maine, and indeed throughout New England, the drainage area of the Cobbosseecontee, up to this time, had been sparsely settled farming country, with many stretches of woodland, and no sources of dangerous contamination to the stream within thirty miles of the intake. Moreover, the great number and large area of the ponds in the Cobbosseecontee system had furnished a sufficient safeguard against the nearest source of serious pollution at Winthrop. But already the process had begun, which since that time has been going on at such an astonishing rate in Maine, and, in less degree, elsewhere throughout New England. People had discovered the great outdoor world, and cottages, camps, and shacks of every kind were beginning to appear on the shores of every pond and stream — and with them came the motor boats. The probable result of this development was evident from the first, but its rate of progress was beyond conjecture. The water of the stream which had been called the best public supply in the state, was still safe — indeed, excellent — but even at that time the case was well expressed by Mr. Safford, our engineer, who said, "Some day in the future you will have to face the problem of filtering this water."

The trustees had, it will be seen, a serious problem on their hands. To make good all deficiencies and bring the plant up to full efficiency promised to absorb all the resources of the district for some sixteen years, at a time when there was an insistent demand for lower rates. Moreover, this was the time when the responsibilities of public-service corporations were beginning to be better understood, and the trustees soon realized that all reasonable demands for extensions must be met, provided the general income of the district would take care of them. With all this

expense on their hands, the trustees could only "sit tight," while camps were going up on every few rods of shore front, motor boats were multiplying by the score, and the water was being rapidly relegated to the semi-polluted class, meeting the danger as best they could by inspection and regulation.

Problems of water supply in this country usually take for granted an increasing population, but the very slight increase in the population of the state of Maine, for many years, has been confined to the larger cities, while that of the Gardiner Water District has been constant at about eight thousand for decades. The fairy tales of growth, of which we read in water reports, were not for us. But, fortunately, the rule of increasing use of water by regular takers held good, extensions brought in much more income than had been estimated, and the situation was saved. Though rates had been twice reduced, the filter plant, which was no more than a dream in 1910, was undertaken in 1914 and the water was turned on in March, 1916.

The description of the filter plant here following is by Mr. Arthur T. Safford.

In the spring of 1912 the engineer was asked by the trustees of the Water District to visit Gardiner and look over the conditions from the pumping station up the stream as far as Pleasant Pond, particularly the danger of pollution just above the station, and the sources from which sediment from the banks and pollution from the camps might get into the water supply; and at that time he discussed with the trustees the wisdom of carrying the intake above the immediate pollution around the station, which did not appeal to the engineer on account of the expense and the partial remedy it offered. The engineer had acted with the late Freeman C. Coffin for the district in the summer of 1903, at the time of taking over the water works, and, from this previous study of the system and tests of its capacity, was already familiar with its needs.

In July of the same year the engineer sent a written statement to the trustees showing a suggested location for some slow sand filters of 1 000 000 gal. per day capacity and clear water basin of 700 000 gal. along the river below the present pumping station, but which did not occupy the Spear lot. The amount of river

wall and necessary arrangement of the filters, which was not of the best from the operating standpoint, required by the first plans, made the purchase of the Spear lot advisable, and the trustees very wisely obtained title to this lot. In the statement of the engineer, it was estimated that the cost of the structures as outlined would be approximately $74 300, including filters, clear water basin, gravel and sand, pipe, connections, centrifugal pump and river wall, " with the hope of some saving over the figures given." The saving over this figure never materialized, and the work cost just about the figure named. On March 28, 1914, about two years later, after providing the " sinews of war," the trustees visited Lawrence, Mass., saw the operation of the filters there, and soon after made preparations to begin work on the Gardiner plant.

During that spring and early summer the trustees made surveys of the land and dug test pits through the land available for filters, and brought up to date all information necessary for an enlargement to the pumping station and necessary connections between it and the filter plant. On May 29, 1914, the engineer made a further report to the trustees upon the important question whether there was water power enough at dam No. 8, the waterworks dam, to do all the pumping into the system and also lift the water to the filters. The engineer advised auxiliary power in reserve for pumping to the filters and to meet a definite shortage of the power for pumping into the mains which exists now at times of extremely low flow. This shortage amounts to about eight days average per year, in twenty-two years, with one of forty-five days in 1911; but the district has gotten through these periods by economizing on water.

In June of 1914 the engineer was authorized by the trustees to prepare plans and specifications for the new filters, which plans it was intended should be ready about the first of July; but a restudy of the problem, which was only possible through details which were then drawn out for the first time, made certain changes in location absolutely necessary, which delayed the plans until August of 1914, about a month after the time set; but it was the month which was most essential for work if the filters were to be

completed that year. The trustees, however, went ahead just as if the work was to be completed in 1914.

Some idea of the work and quantities involved may be gained from a portion of the advertisement in the *Engineering News*.

I. Sealed proposals for the construction of a covered slow sand filter together with all piping, fixtures and appurtenances, for the Gardiner Water District of Gardiner, Me., will be received at the office of the Gardiner Water District in the City of Gardiner, Me., until 3.00 o'clock P.M. the eighth day of September, 1914.

. . . . . .

VII. Bids will be compared with the basis of the following estimates of quantities of work to be done:

| | | Actual Items. |
|---|---|---|
| Item 1. Cofferdam and all protection work. | | |
| Item 2. Excavation | 7 750 cu. yds. | 9 000 |
| Item 3. Rock excavation | 900 cu. yds. | 2 024 |
| Item 4. Concrete in floors | 955 cu. yds. | 1 325 |
| Item 5. Concrete in walls | 1 280 cu. yds. | 1 280 |
| Item 6. Concrete in piers | 85 cu. yds. | 85 |
| Item 7. Concrete in roof | 770 cu. yds. | 800 |
| Item 8. Arch centers | 27 300 sq. ft. | 27 300 |
| Item 9. Cast-iron pipe, 6 in. to 18 in. | 30 tons. | 24.39 |
| Item 10. Cast-iron specials and flanged pipe | Shown on plans. | |
| Item 11. Gate valves and appurtenances | Shown on plans. | |
| Item 12. Controller, regulating valves and indicating apparatus | Shown on plans. | |
| Item 13. Structural work, ladders, floor plates, supports, and castings | Details furnished. | |
| Item 14. Interior tile drainage system and roof drains | Details furnished. | |
| Item 15. Filter gravel | 220 cu. yds. | 318½ |
| Item 16. Filter sand | 2 400 cu. yds. | 2 370 |
| Item 17. Entrances and operating chamber | Shown on plans. | |
| Item 18. Reinforcing material | 15 000 lbs. | 23 595 |
| Item 19. Exterior tile drainage system | 375 ft. 12-in. tile.<br>50 ft. 4-in. tile. | |
| Item 20. River wall-concrete | 150 cu. yds. | 150 |
| Item 21. Seeding | 1 acre. | 1 acre. |
| Item 22. Extra work. | | |

LORING C. BALLARD,
HENRY RICHARDS,
EDWIN L. BUSSELL,
*Trustees of the Gardiner Water District.*

During negotiations with contractors, there appeared the following difficulties in the way of attempting to complete the filters in 1914:

The lateness of the season; the difficulty in the way of getting sand, gravel, and crushed stone; the amount of excavation required before any concrete could be poured, — the amount of rock being more than twice that of the estimate; the test pits showed simply the low spots, not the high.

For this reason all previous bids were rejected and revised bids called for, opened on October 1, 1914, and the contract awarded to James H. Ferguson, of Boston, Mass., the lowest bidder. Mr. Ferguson carried on the work until June 12, 1915, when much of the excavation was done but little concrete poured; after which time, and under a settlement satisfactory to both parties, the district took over the work and finished it by day labor under the direction of the engineer, during the year 1915.

The design of the filters was based upon the need of filtering approximately 700 000 gal. per day, most of which was pumped during the day hours; a soft, pure water, drawn originally from enormous storage through a comparatively small pond, — Pleasant Pond, — through six miles of shallow stream likely to be overflowed over meadows of fine river silt to dam No. 8, where the 700 000 gal. a day, or the one cubic foot per second pumped into the system with over one hundred other cubic feet for power, is drawn directly from the river into the water-wheel flume. No change in the intake was made in connection with building the filters. There is therefore no chance to settle out any sediment before it is pumped to the filters.

An analysis of the water made in 1911 follows:

CHEMICAL AND BACTERIAL ANALYSIS OF SAMPLE OF WATER FROM GARDINER, ME., APRIL 4, 1911.

(Parts per 100 000.)

| | |
|---|---|
| Chemical number | 55 361 |
| Bacterial number | 7 163 |
| Turbidity | Slight |
| Sediment | Decided |
| Odor | Zero |
| Color | .16 |

| | |
|---|---|
| Free ammonia | .0066 |
| Albuminoid ammonia, total | .0152 |
| Albunminoid ammonia, in solution | .0130 |
| Nitrogen as nitrates | .006 |
| Nitrogen as nitrites | .0002 |
| Oxygen consumed | .18 |
| Chlorine | .280 |
| Hardness | 1.2 |
| Iron | .0280 |
| Solids — unfiltered. Total | 3.3 |
| Loss on ignition | 2.1 |
| Fixed | 1.2 |
| Solids — filtered. Total | 3.0 |
| Loss on ignition | 2.0 |
| Fixed | 1.0 |
| Bacteria per c.c., 20° C. | 12 500 |
| Bacteria per c.c., 40° C. Total | 20 |
| Bacteria per c.c., 40° C. Red | 6 |
| B. coli, 1 cubic centimeter | 0 |
| B. coli, 100 cubic centimeters | 0 |

April 8, 1911.

The growth to provide for was the immediate addition (1914) of South Gardiner and (1915) upper Farmingdale, some increase in population through the district, and the inevitable increased use due to improved methods of living. Ultimately, twenty-four hours pumping will be necessary, and a more rapid rate of filtration than the present one; and finally the general use of meters, all before the filter plant will have to be increased.

The filters and clear water basin, with the superintendent's house, — which hung over the abyss for about one year, — and his barn, which was moved from the site of the clear water basin, occupy about an acre between Central Avenue, the pumping station and Cobbosseecontee stream, about a mile up from the Kennebec River and the business district, the filters — four in number — being at the east or end furthest from the station and the clear water basin at the west end. The north end of the area occupied by the filters and clear water basin is limited by the river; and a heavy concrete river wall was necessary to complete the slopes.

The main supply pipes to the city, and the mains to and from the filters, are all in the lawn and driveway in front of the station

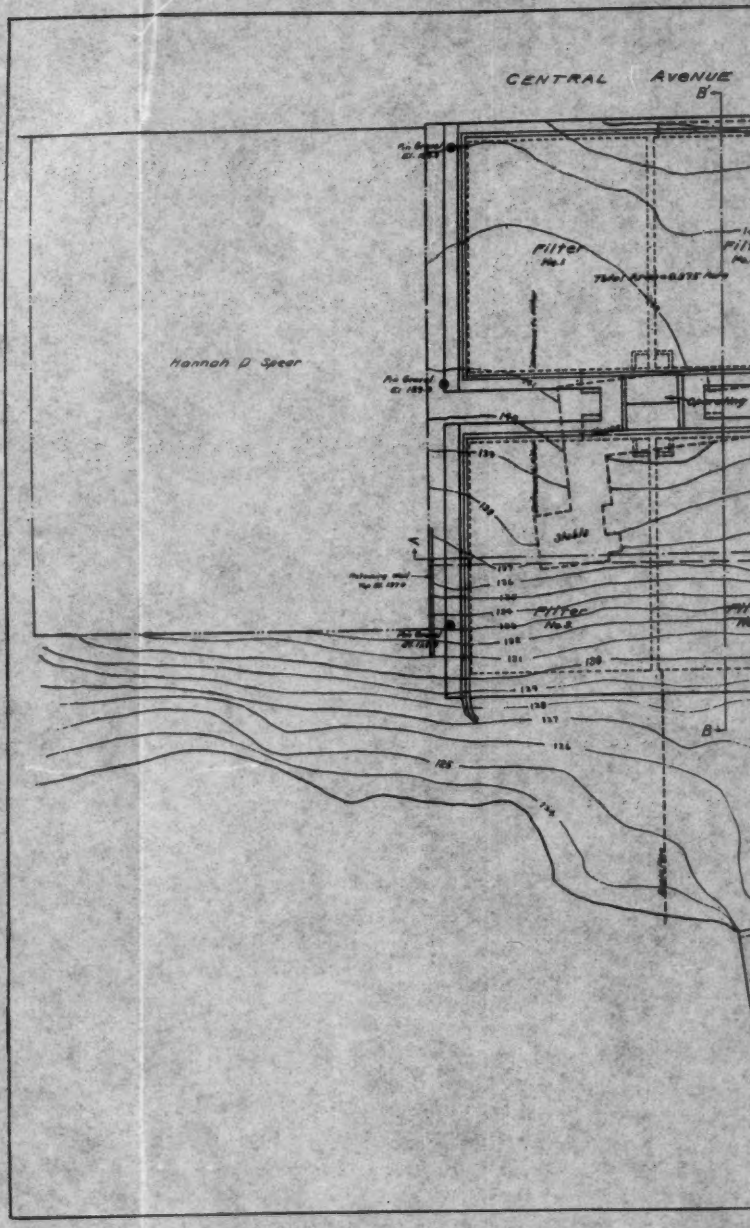
and west of the clear water basin. Connections are made from this point to the operating chamber in the middle of the acre lot between the two filter units and the southeast corner of the clear water basin. The elevations of water are:

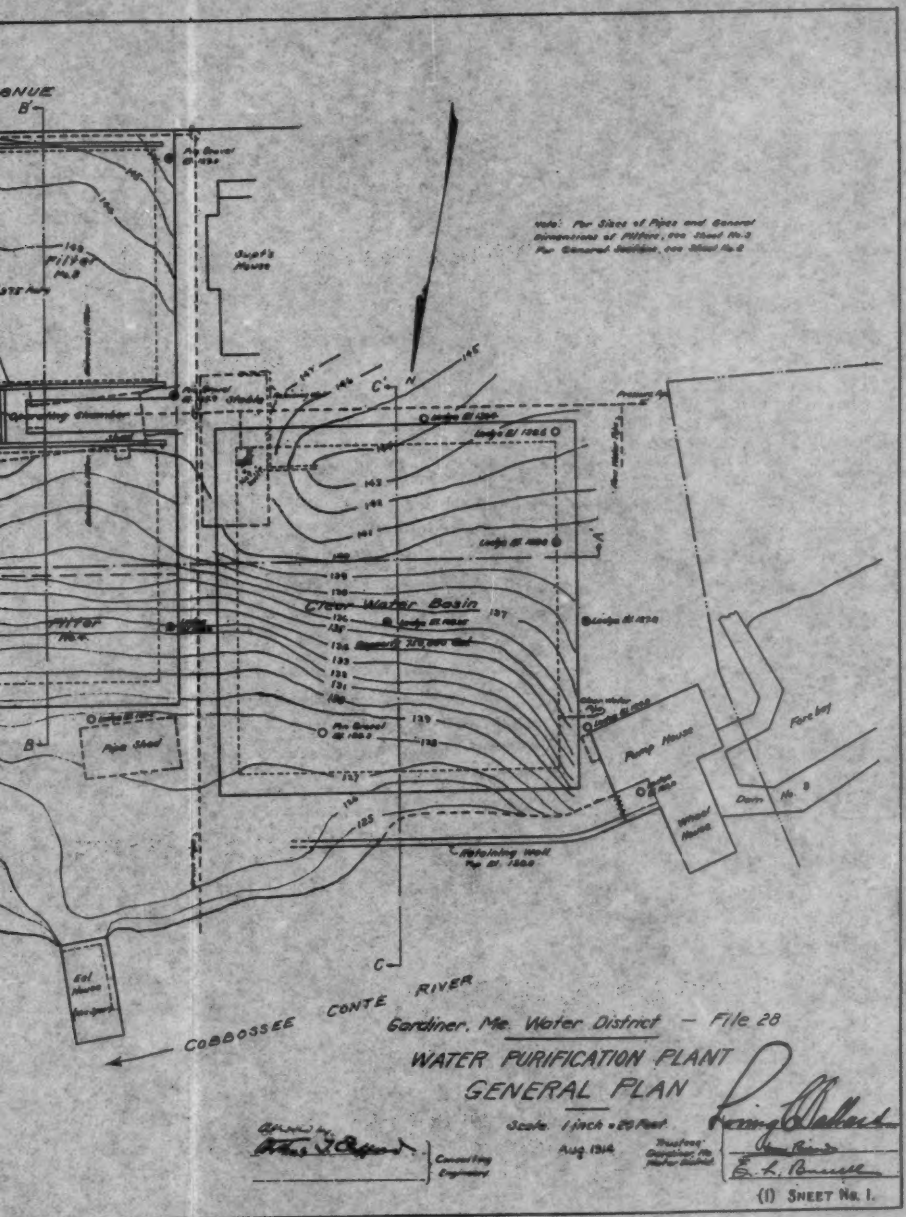
| | |
|---|---|
| High water in the Cobbosseecontee stream above the dam | 136.8 |
| High water in the filters | 144. |
| High water in the clear water basin | 137. |
| High water in the Cobbosseecontee stream below the station | 126. |

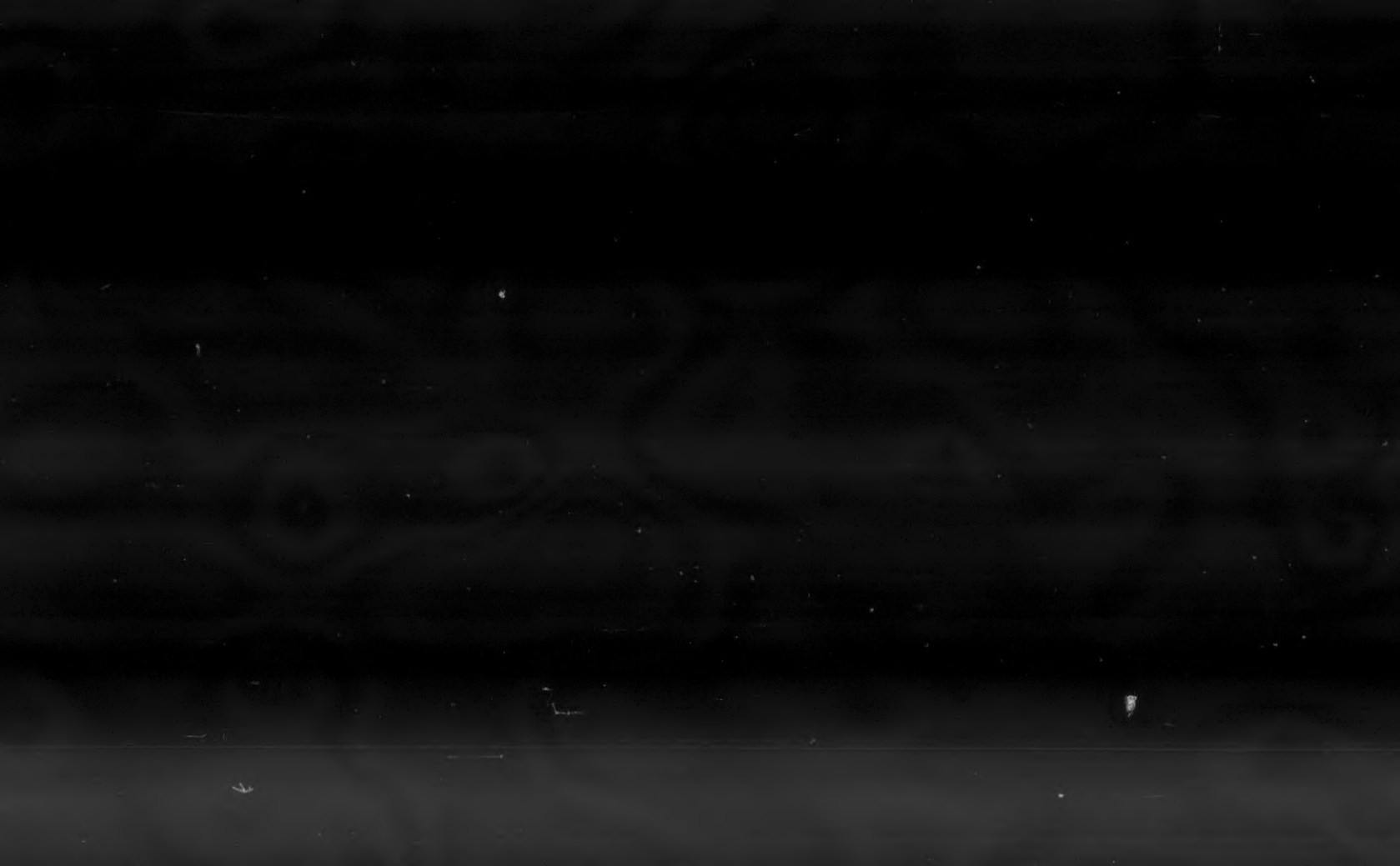
All above tide water.

The filters consist of four units of 20 squares, each 55 ft. by 73 ft. 4 in. inside dimensions and 12 ft. high. Practically all of filters 3 and 4, the most northerly, were on filled ground. The east walls against the Spear lot are practically vertical walls 10 ft. high, 18 to 24 in. thick, but with broad bases and heavily reinforced against the roof of the filters; the north, west, and south walls are of aqueduct section 4 ft. thick at the bottom. Each pair of filters is separated by a division wall 3 ft. 6 in. at the bottom and 2 ft. at the top and 9 ft. high. All piers are 2 ft. 4 in. at the bottom, 20 in. at the top, the end walls and piers supporting a vaulted roof 6 in. thick at the center of the arch, but carried level over each pier. The bottom is an inverted arch, 6 in. thick. In the middle of each bay are 3 ft. manholes with ordinary iron covers. The clear water basin is 100 by 100 ft. inside, and consists of 49 squares 14 ft. 2 in. by 14 ft. 2 in. The end walls are 12 ft. high of aqueduct section, 4 ft. thick at the bottom, with piers 2 ft. 4 in. at the bottom and 20 in. at the spring. The clear water basin is built on ledge, excepting the three bays nearest the river, which are on fill. In addition to the east wall, the roofs of the filters and clear water basin were reinforced by $\frac{3}{4}$-in. rods in pairs across each other over the tops of the piers.

A 15-in. tile effluent pipe, set in concrete, runs north and south beneath the floor of each filter. This is connected through a 15-in. by 10-in. tile reducer to a 10-in. cast-iron pipe into the operating chamber. Five 15-in. tees, one at the center of each bay, allow water to enter the effluent pipe. Ten-inch split tile drains running north and south and east and west along the centers of the bays bring the water to the tees.


CENTRAL AVENUE
B
Hannah D Speer
Filter No. 1
Filter No. 2
A
B


Clear Water Basin
Filter No. 1
Filter No. 2
Supt's House
Pump House
Pipe Shed
Retaining Wall
Dam No. 8
Forebay
Coal House
Note: For Sizes of Pipes and General Dimensions of Filters, see Sheet No. 2
For General Section, see Sheet No. 3
COBBOSSEE CONTE RIVER
Gardiner, Me. Water District — File 28
WATER PURIFICATION PLANT
GENERAL PLAN
Scale 1 inch = 20 Feet
Aug. 1914
Consulting Engineers
Trustees
(1) SHEET No. 1.



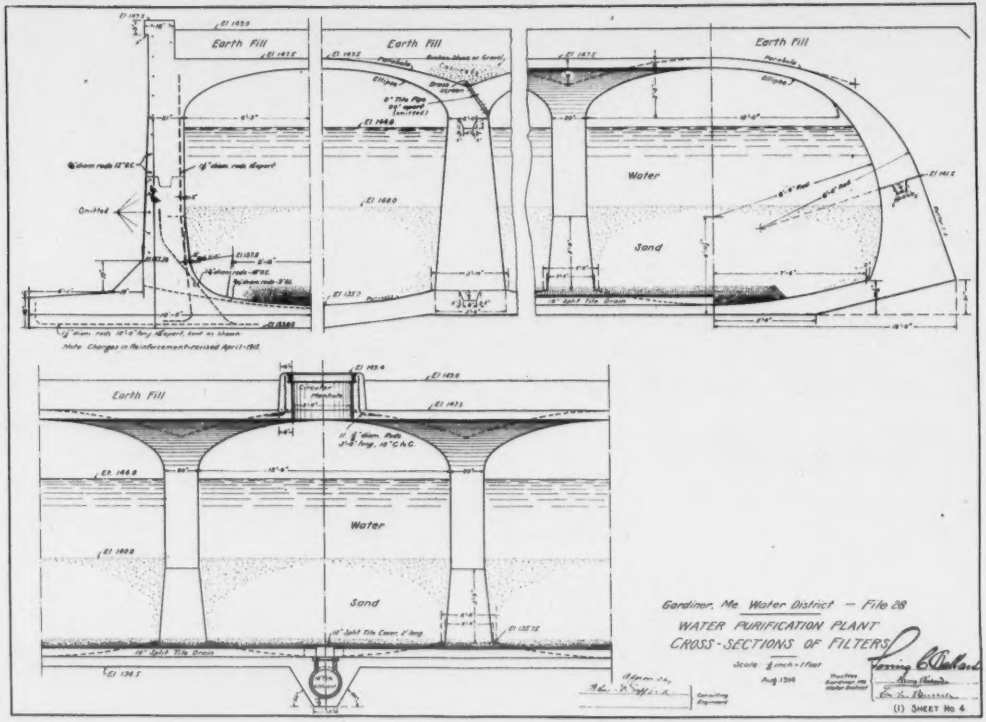



FIG. 1.

CROSS-SECTION OF FILTERS.

The split tile drains are covered with gravel, graded from coarse at the bottom to fine at the top, 1 ft. thick and 6 ft. wide. Above this and covering the entire floor of the filters is a layer of sand 4 ft. thick. This is carefully leveled off at the top, and the raw water stands 4 ft. above the top of the sand.

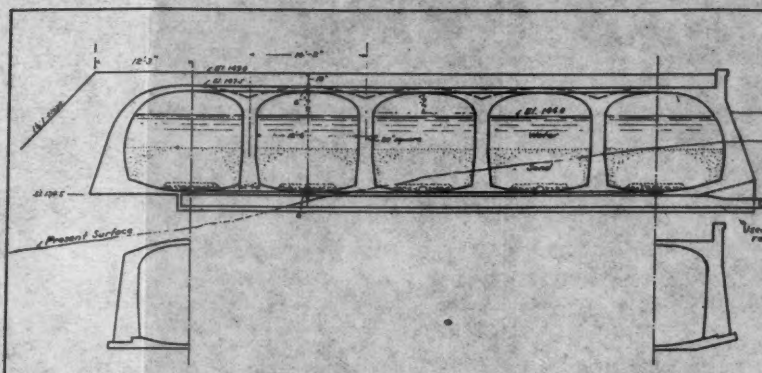
The raw water is pumped from the river by a centrifugal pump through a 16-in. cast-iron pipe to the operating chamber, whence it is delivered to all or any of the filters through 12-in. cast-iron pipes fitted with regulator valves. After being filtered, the water runs by gravity through an 18-in. cast-iron pipe into the clear water basin and from here is pumped either directly into the city mains or to the reservoir by the two pumps in the station.

The operating chamber contains all the valves to regulate the flow of water into and from the filters. It also contains gages (of the clock type) registering the amount of water filtered and the rate of filtration. This is done by means of Venturi meters set in the 10-in. cast-iron outlet to the effluent pipes.

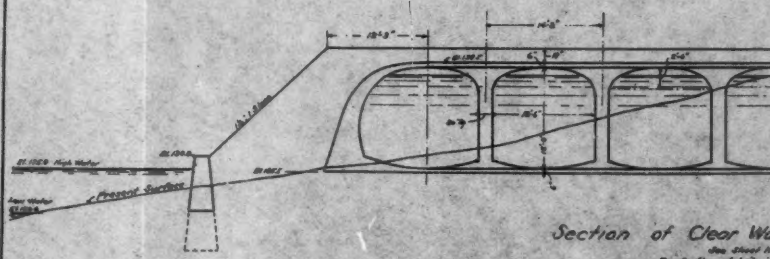
The runways into the filters consist of three 3-in. by 8-in. hard-pine planks, 18 ft. long, supported at the upper end by a concrete sill and at the lower end by a 6-in. 12¼-lb. I-beam with its ends set in the concrete of two adjacent piers. The lower end of the planks is level with the top of the sand in the filters. This runway and the operation of cleaning were made as simple as possible due to the very infrequent cleaning necessary for some years.

The general design of the raw water and effluent systems is similar to that in the Lawrence, Mass., filters, and there are no special problems of design which have not been worked out successfully elsewhere. The problem was particularly one of getting materials to the spot and of building filters on that location suitable to the needs of the district and which would be ready for immediate use when finished, without the usual experimental period.

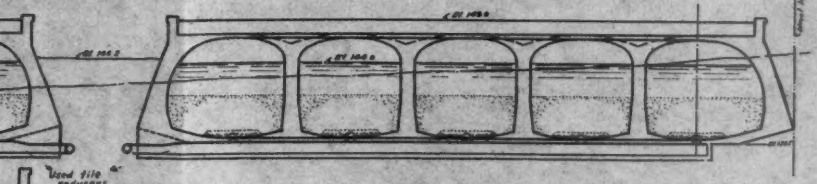
Friendly suggestions were given the engineer by old business associates, Mr. Harry W. Clark, of the Massachusetts Health Department, and Mr. William S. Johnson; and his assistant Mr. Guy S. Deming carried on his shoulders the responsibility of the work.




Section of Filter and Clear Water Basin

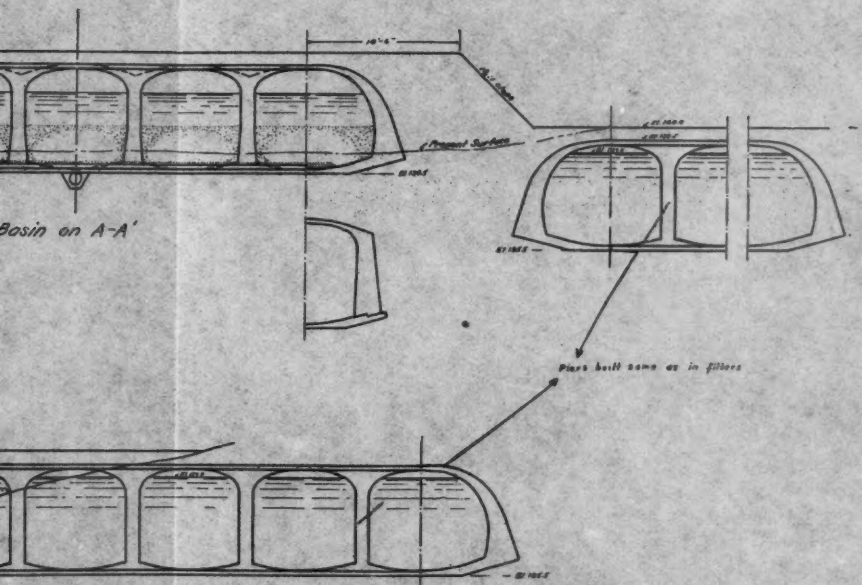



Section of Clear Wa



Section of Filter on B-B'

See Sheet No. 1
For further details see Sheets No. 4&5.



Basin on A-A'

Piers built same as in filters



Clear Water Basin on C-C

See Sheet No. 1
for details see Sheet No. 6

Gardiner, Me. Water District. — File 28

WATER PURIFICATION PLANT
GENERAL SECTIONS OF FILTERS

Scale: 1 inch = 1 Foot

Aug. 1914

Loring Wallace
Trustees Gardiner, Me. Water District

(1) SHEET No. 2.

Mention has been made of the difficulties in the way of getting materials. As finally selected, they were as follows:

4 550 barrels Lehigh cement at a price of $1.68 a barrel in Gardiner.
3 370 cu. yd. stone from within two miles of the job, hauled by teams and crushed at a final cost of $0.88 per cu. yd.
2 025 cu. yd. sand for concrete, screened, from the Haley bank and landed on the job at $1.23 per cu. yd.
2 370 cu. yd. sand for filters from Merrymeeting Bay, dredged, brought in lighters, and hauled to job at a final cost of $1.95 per cu. yd.
318½ cu. yd. of selected gravel around the underdrains and landed on job at a cost of $5.72 per cu. yd.

The 3 640 cu. yd. of concrete were placed at a total cost of $30-079.09 and an average price of $8.26 per cu. yd., the excavation cost $6 935.75, or $0.77 per cu. yd; the rock excavation, $4 552.88, or $2.25 per cu. yd.

The ground water flow was picked up by a 12-in. exterior tile drainage system and carried to the river.

At the time the district took over the work, after nine months, most of the excavation had been done, but only 337 cu. yd., or 9.2 per cent., of the concrete had been poured, and this the roughest part in the bottom of the filters. There was left on the work certain apparatus (most of it insufficient), supplies, forms, pipes and specials, all of which were inventoried and paid for. The basis of the settlement with Mr. Ferguson was businesslike to the extreme; the trustees paid him for what he did, at his contract prices, and bought his materials for what they cost him.

The trustees, between July 8 and July 19, 1915, cleaned up and made safe the job; bought necessary supplies, revamped the contractor's old outfit, and built new apparatus, runways for landing sand and stone, and completed the job, including most of the additions to and connections with the pumping station, in twenty-five weeks. No portion of the work was faulty, excepting the few cracks to which Mr. Richards refers below; nothing had to be done a second time and, with rising prices for materials and labor, the work has been completed and the filters started for the sum of $71 000, not including some credits.

For the future there remains to operate the filters to the best advantage and in the best manner, which can only be found out

by trial; to bring out the filters to their fullest capacity; and by constant chemical and biological analyses keep the filters in the best condition to free the water from pollution and make it as palatable as possible.

In the judgment of the engineer, the only problem which remains is an excess of sediment in the raw water at certain times in the year. This may not overtax the filters for some years, but is likely to cut down their capacity very materially for short periods of time. The remedy is a simple one: to change the intake, which now being in the current to the water wheel is in a place where all sediment of all sorts is drawn towards it, to a location a little further upstream and behind a timber crib or concrete bulkhead, so designed that all the water pumped to the filters shall be drawn from a middle level, neither top nor bottom, after most of the coarse sediment will have been deposited. This bulkhead may be arranged in such a way that the water can be cut off and the sediment removed from time to time.

Additional filters and continuous pumping twenty-four hours in the day may come, in spite of meters, if the population of Gardiner increases materially in the future, but such an increase will bring with it increased revenues, and there is nothing about the filters or the present location which will prevent extending or using the filtration plant for a larger consumption of water.

If there is much pumping to the reservoir during hot weather, the reservoir may have to be covered.

[At this point Mr. Richards takes up the story.]

A few points remain that may be of interest. Sand for local use is brought up river from Merrymeeting Bay — in effect, a great shallow lake in which all the detritus brought down by the Androscoggin River is deposited at its junction with the Kennebec. It had been supposed that clean, sharp sand of almost any required grain or grading could be obtained from this source, but this proved entirely unsuitable for concrete, and after testing samples from a wide range of localities, satisfactory sand for concrete was at last found in a bank built up of river dredgings, deposited by the Federal Government a couple of miles below South Gardiner. It is worth noting, perhaps, that of a dozen or so of

these banks, deposited at various points below Augusta, this one alone gave satisfactory results.

While the question of sand for concrete was still unsettled, the contractor, a rather headstrong person, with more zeal than discretion, landed a large quantity of " Bay " sand at the site on his own responsibility, and this sand was a bone of contention for many weeks. Being conveniently at hand, it was tried as filter sand in the model filters in which the problems of filtration were being worked out, and showed decidedly better results than the specification sand prepared for the purpose.

The results thus outlined suggested, first, the great need of sand graded to specification at a reasonable price. Such grading as is done seems to be prohibitive in price, or, for various reasons, is not to be depended on. The lack of a material exactly suited to the specific purpose in hand is the secret of much failure in concrete. The results described suggest, secondly, the question whether the considerable percentage of mica, present in the " Bay " sand, which was the probable cause of its failure in concrete, may perhaps have been the reason, or one of the reasons, for its success as filter sand. To the writer, it seems reasonable to suppose that flakes of mica of the right size and in suitable proportion might possibly serve as accessory agents to the *schmutzdecke* in retarding the flow through the filter and increasing its efficiency.

Some experience with cracks in the concrete may be not without interest. A contraction crack in the roof of the clear water basin was not unexpected and was easily taken care of. A second crack,— possibly a " cold shut " between two layings of concrete, in the wall between filter No. 1 and the controlling chamber, took care of itself in a short time. But two cracks in filter No. 3 were rather inexplicable, and caused some trouble. One of these cracks appeared near the west side of the roof of this filter, extending across the roof to the eastward, opening to about three eighths of an inch in the parapet, continuing down the east wall, and dying out near the toe of the wall. As this crack showed lateral without vertical displacement, it might have been due to insufficient filling on the north side (the filling on this side was incomplete and not well packed when the filter was filled), but, unfortunately for this theory, there was a second crack in this same

filter, which outlawed it. Neither of these two cracks appeared until after the filter was filled with sand, nor was the second one suspected until the filter was in operation on a flush-out run, when daily samples of effluent water were being sent to the State Laboratory, bringing regular reports of B. coli from filter No. 3. This most unexpected and unwelcome development furnished much food for thought, until finally the suggestion of a crack in the bottom of this filter explained the whole matter. The filter was drained, the sand was shoveled back, and the crack was discovered in the floor, almost immediately below the crack in the roof just described. This second crack began in the partition wall between filters Nos. 3 and 4, near the surface of the sand, extending down the wall, well across the floor, then turning and running out through the north wall. Ground water from the rotten ledge underlying the filter had come in through this crack, explaining the presence of B. coli, but any movement that could have caused the first crack was negatived by this one. The conclusion was that both were contraction cracks, caused, possibly, by the exposure of the unfilled filter for many weeks to extremely low temperatures.

After many experiments it was found that the cracks were most effectively stopped by calking with lead wool. Wisdom after the event suggests more horizontal reinforcement in the outer walls, and ample reinforcement in the floors of the filters.

Our experience in cleaning filters may be worth recounting. The filters were turned on March 24, and the practice of running three filters, with one in reserve, has been followed from the beginning. The first partial clean-up was made June 3, when the surface of the middle sections of all the filters was loosened up and some of the *schmutzdecke* was removed. Filters No. 3 and No. 4 were thoroughly cleaned, September 15. October brought heavy rains, and the raw water was loaded with silt. All four filters were cleaned November 1, when half an inch of mud was found on top of the *schmutzdecke*. The filters are now expected to run without further cleaning until April 1.

The practice in cleaning is to drain the filter, let it stand three days for the *schmutzdecke* to dry, when it is very easily removed with flat steel shovels. The surface of the sand is then loosened

up and leveled off with steel rakes, and the filter is ready for work. The total loss of sand from cleaning since the filters were started is little more than one inch.

In conclusion, I should add that the results obtained from the filter are better than was expected and all that could be asked. The reduction in bacteria count has been ninety-eight per cent. almost uniformly. The removal of objectionable flavor has been very satisfactory. The reduction in turbidity, even under the worst conditions, has exceeded all expectations. Perhaps the best comment on the whole operation is found in the facts that the Hazzard shoe factory, employing sixteen hundred hands, which formerly paid a local spring-water man so much per capita per week for a supply of drinking water, has now put in bubbling fountains, and is using filtered Cobbossee water with marked satisfaction,— and in the change from almost unanimous popular condemnation of the filter and all its works, with the men responsible for it, to an equally unanimous chorus of praise and congratulation.

One further point has been noticed. Since the filter was started, the growth of " tubercles " in the water-ways of our 12-in Blake pump has decreased something like ninety-five per cent , and if there has been anything like an equal reduction of interior concretions in the cast-iron pipes, the effect is significant.

## Discussion.

Mr. A. T. Safford.* I am not going to say very much this afternoon because the discussion I agreed to give has been written into the description of the filter. You must have realized, in hearing this paper, how much has been done by the trustees of the Gardiner Water District in preparing the public for an improvement like this.

There is no question in my mind that the Cobbosseecontee stream is about as good for water supply purposes as you would expect to find, certainly out of Massachusetts. And I question, if the trustees had let this supply go on without filtration, whether they would have been very seriously censured. Usually it takes

* Consulting Hydraulic Engineer, Lowell, Mass.

an epidemic of typhoid to start the public. The best thing about the Gardiner plant as a first slow sand filter in Maine is that all these surface waters in time will have to be filtered; and now, when a municipality in Maine wishes to talk about filtration, they can point to the fact that the city of Gardiner has made the start, has made it successfully, and paved the way for a great many other filters.

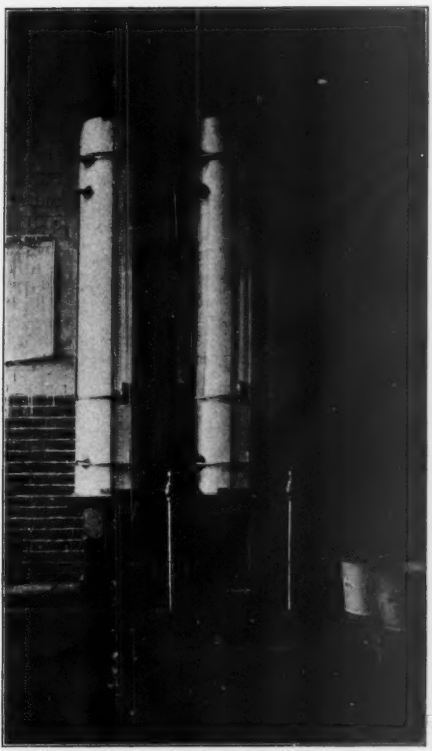
Some description of the experimental filters may be interesting.

These filters or tanks, made of galvanized iron, were exactly similar in design, 6 ft. high and 20 in. in diameter. There were three taps for loss of head gages arranged to give the loss of head through the upper three inches of the sand layer and through the total depth of the sand. The water supply to the tanks was controlled by ball-cocks, and the rate of filtration regulated by the effluent valves. In order to approximate as closely as possible the operating head which would obtain in the filters themselves, without building the test tanks to the full height of the filters, the effluent pipe was extended down about three feet and sealed in a pail of water from which the overflow lead to a sewer. By employing the principle of the draft tube, the height of the tank was kept down to a convenient figure. The two tanks, fittings, gage glasses, all set up ready to receive the sand, cost about fifty dollars. (See Plate VI.)

One of the tanks was filled with sand, furnished and graded by Green & Wilson, of Waterville, Me., to conform to the specifications for filter sand (practically the Lawrence, Mass., specifications). The other tank was filled with the so-called "Bay" sand, which the contractor had delivered on the job and which, bought for concrete, was rejected on account of the excess of mica.

The lower six inches of each tank was filled with coarse, clean gravel, and the sand carried up four feet to a level about half way between the upper two gage taps.

While the engineers were at work planning and testing out the experimental filters, we had a great deal of assistance from Mr. Richards, whose occasional picturesque criticisms kept the problem clearer before us. Without his permission I give a portion of an interesting letter from him which was received during the preliminary work of the experimental filters:



VIEW OF EXPERIMENTAL FILTERS.

"The experiments which Mr. Deming is trying with the model filter seem to be directed exclusively to determining the capacity of our filter plant. They will show — in fact, they have already shown — that with clean 'specification' sand we could run an enormous amount of water, in excess of our needs, through the filter. Later on they will show the rate of slowing down, and the time required, under different conditions of raw water, to reach the minimum fixed by our consumption. They will also show the comparative capacity of 'specification' and 'Bay' sand, under the changing conditions from 'free' to 'choked.'

"All this is good, so far as it goes; but, when all is done, it will show only that the rat can get through the hole, which we soon determined, and it does not prove that the material we are using is in any way better than chicken-wire or paving stones.

"The essence of the whole business of filtration, as I understand it, is in the bacteriological action that occurs in the filter bed, and I suppose there must be certain well-determined relations between the rate of flow and the gage and grading of the sand that are essential to the development and maintenance of this bacteriological action. If this be true, and since our rate of flow is fixed by our consumption, the point seems to be to determine the gage and grading of sand that will maintain the bacteriological action under our constant flow when the sand is clean and maintain the flow to reasonable limits of choking. There you have a range, say, from *a* to *b*, which should be expressible in gallons per minute, per square foot, or whatever, within which we must keep if we would have the filter effective."

The tanks were first set up in the water board office, and a number of preliminary runs made to test the apparatus. On April 14, 1915, during the spring, when the work of pouring concrete for the filters was really begun, the two filters were drained, dismantled, and moved up to a new location at the pumping station, where they were supplied with raw water directly from one of the main supply mains at a point just beyond the check valve. On April 19, the two filters were again in operation at a 3 million gallon per acre daily rate. On May 3, samples of raw water from the pumping station forebay and the effluent from each of the test filters were collected and sent to the State Laboratory of Hygiene in Augusta, for analysis. The analyses showed positive tests for B. coli in 1 c.c. of the raw water, and a warning notice to boil the water was published in the local newspaper. The effluents of the two filters were good and the percentage of bacteria removed high,

considering the short time the filters had been in operation. (Analyses on page 224.)

The filtration rate was then increased to 4 million gallons per acre daily, and further analyses were planned for, to determine whether or not the new rate was too high for efficient filtration.

From May 8 until May 25, 1915, the two test filters ran at a rate of 4 million gallons per acre daily, when the rate was increased to $4\frac{1}{2}$, and on May 26 to 5 million gallons per acre daily. On May 17, samples were collected as before and analyses made by the State Laboratory of Hygiene. Neither of the filters showed any signs of breaking down under the increased rate, though No. 1, containing "specification" sand, indicated greater biological activity than No. 2, containing "Bay" sand. The removal of bacteria at 37.5 degrees was 98 per cent. for each. The maximum total loss of head to date (June 12, 1915) in No. 1 is about 0.68 ft., and in No. 2 about 1.04 ft., each filter showing a gradual increase.

By the settlement between the trustees and the contractor, the former agreed to take the 644 cu. yd. of "Bay" sand which the contractor had delivered on the job but was rejected for concrete. The performance of test filter No. 2 indicates that this sand could probably be satisfactorily utilized in the filters, and the tests carried on without interruption throughout the summer and fall gave no reason to alter this conclusion.

# SOME PROBLEMS OF WATER SUPPLY SANITATION IN NEW HAMPSHIRE.

BY CHARLES D. HOWARD.*

[*Read September, 1916.*]

New Hampshire is fortunate in the natural excellence of its public water supplies. Of slight coloration, extremely low mineralization, with relative freedom from troubles due to microscopic organisms, and the lesser risk of contamination inherent in more populous sections, those of the Granite State are, as a group, unexcelled.

Where, in New England, can one find a finer water system, or a more remarkable source, than the flowing artesian supply of the Pennichuck Water Works at Nashua, — President Sullivan's system. Continually boiling up out of the ground is soft spring water, in quality unexcelled by any water anywhere, and in quantity supplying a whole city. While we must admit that there are, unfortunately, a few supplies of which we are not proud, yet we feel justified in claiming that, as a result of the application of some form of treatment, there is not one at the present time seriously liable to be a direct cause of disease.

Sanitary control of water supplies was effected by the state board of health in 1902, with the establishment of the state laboratory of hygiene. Sample collections are made of the various supplies a number of times each year, those from some of the larger systems averaging once a month, or oftener. In addition, numerous watershed inspections are made and advice given as occasion arises.

Out of a total of 116 public water systems, sixty-two, or slightly over one half, are derived from surface sources, the latter in most cases representing natural or artificial ponds or lakes. While the small impounded woodland or mountain brook is frequently resorted to, streams of a size to warrant the name of river consti-

* Chemist State Board of Health, Concord, N. H.

tute a regular source in some three or four cases only, and in but two of these is the water appreciably subject to contamination, a purification treatment being applied in each instance.

It must be admitted, however, that, in the case of the systems using ground water, practically all of these have an emergency intake in some pond or stream. We realize that these emergency intakes, no matter how infrequently they may be resorted to in practice, constitute one of the problems of insuring a continuously pure water supply. It is true that a large share of these secondary sources are passably good; yet a lot of them are not, and even though these may be requisitioned only in case of an extensive fire, or for brief periods of unusual shortage, the desirability of a system of check and control in such cases by a central authority is recognized by our department.

Approximately 45 per cent. of our public systems are municipally owned. Of the 55 per cent. privately owned, most are small supplies. It seems to be our experience that the supply under private ownership is apt not to be a good thing for the consumer, although this is not nearly so true to-day as it was a few years ago. One such company was recently put out of business because of failure to heed the murmurs of its patrons and its unwillingness to expend a few thousand dollars for the installation of a quite indispensable filter-plant for the removal of excessive color. One or two other companies are likely eventually to find themselves in a similar predicament, due to the same reason. Consumers everywhere are becoming more critical as to the physical character of the water they drink, and the prediction is ventured that the day is not far distant when it will be demanded that all of our public supplies shall have the general attributes of spring water.

Relatively few of our waters are, however, concerned with the color problem, and difficulties due to odor and taste, although arising now and then, are generally of very limited duration and have never proved especially troublesome. Turbidity is of course something we know very little about. Practically the only sources whose natural turbidity approaches in any material degree to that so generally true of the streams further west are those of Exeter and Newmarket. The former is satisfactorily cared for by

mechanical filtration, with chlorine gas as an auxiliary to alum flocculation, while plans are under consideration for a similar treatment in the latter case. In common with quite a number of municipalities, the town of Newmarket recently sought to get around some of its troubles by resorting to the expedient of deep drilled wells. The result was hardly a success, however, as the quantity was disappointing and the water carried a considerable alkalinity, due to bicarbonate of soda.

Another village which had a decidedly unsatisfactory experience with the deep-well proposition is that of Salmon Falls. This is a compactly built mill town of about 1 500 population, at present rather unique in the respect that it is the only place in the state of any size which does not possess a modern public system, the tenement dwellers being dependent upon a number of sidewalk pumps. A few years ago, in an attempt to improve both the quality and increase the quantity available from these sources, deep drillings were made at the bottoms of three of these wells. Due, however, to the seamy ledge, no improvement whatever resulted over the polluted condition existent in the original wells.

Although it is our experience that a not inconsiderable proportion of the deep wells constructed during the past few years have resulted in an iron-impregnated water, yet it so happens that thus far none of these are a part of any public system. As a rule, our uncontaminated ground waters are very free from iron. Although there are four or five public systems that have a slight amount of trouble at times from this metal, practically there are but two in the state which have given their superintendents cause to really know what iron contamination is like.

Some years ago a number of shallow driven wells were constructed as a supply for the village of Merrimack. The water proving impossibly ferruginous, the company reverted to the original Souhegan River source. When the latter was condemned recently by the state board of health, the matter of utilizing the water of these wells was again taken up and eventually a deferrization treatment installed which involves passing the aërated raw water through a coke filter and subsequently through sand. Although the source is quite rich in iron, the results have been very satisfactory, the removal averaging not far from 95 per cent.

Equally satisfactory iron removal is effected in the case of the Dover supply, which consists of a combination of pond water and ferruginated springs. The latter issue from an iron-bearing sand which is overlayed by a rich muck. At times of rains not only is the iron content increased, but a troublesome acid condition has developed. During 1909 a slow sand filtration plant was installed, partly for the removal of iron and partly to insure the purity of the pond water. The mixture of pond and spring water travels a few thousand feet before entering the aërator, which is of the perforated iron plate type. One beneficial result of premixture with the pond water is that flocculation of the iron is already well under way when the aërator is reached, the subsequent removal through settling and filtration being very complete. Another beneficial and at the same time interesting result of this mingling is in the fact that we have repeatedly found the mixed raw water, as emerging at the aërator, to be practically sterile, showing from one to three bacteria only on agar, and from ten to twenty only on gelatine, as against two or three thousand on gelatine in the original pond water.

Under the terms of a law enacted in 1899, practically all of our surface supplies, including even the larger lakes, have gradually come under the sanitary protection of special regulations promulgated by the state board of health, following application therefor by the local water commissioners. These regulations, of the same general character as those adopted by a number of other states, are enforceable by the local boards of health and carry a penalty for each violation of twenty dollars.

Formerly it was quite the thing for our pond supplies to serve the cities and towns in a dual capacity, and unfortunately the practice is not yet altogether abandoned, although during the past ten years the idea has been fast going out of fashion. Thus the little lake or pond a few miles outside the city has not only furnished the drinking supply for its citizens, but there has been expected of it that it should serve as the local summer pleasure resort, as a trolley terminus picnic ground, a place for boating and fishing. It was no unusual sight to see the shores of the municipal drinking supply lined thickly with summer cottages, with regular lines of steamers or launches plying over the surface during

the season. But of late this sort of thing has been frowned upon; city fathers have regulated, and public sentiment has objected, to such a degree that the possession of such a summer place, in view of all the restrictions imposed and the prohibition against bathing, has become unpopular. Our more progressive cities have long ago adopted the policy of buying up these shore properties and re-foresting the watershed.

In this connection an interesting case has recently come up involving the supply of the city of Concord. This consists of a pond of about 340 acres. When the source was adopted, a dam was constructed upon the outlet brook so as to flow an additional thirty acres of land owned by the city. Eventually this second smaller pond thus created became a sort of harbor for the mooring of boats. Being near the trolley, a public picnic ground was established upon its shores, and here the owner of a line of pleasure steamers constructed his wharves and boathouses. It was always assumed that inasmuch as this was apparently a public body of water within the meaning of the statute, it would be impossible to deprive the public of its constitutional boating and fishing privileges thereon. Recently, following the gradual purchase and removal of practically all of what was once an extensive colony of summer cottages, the city proceeded to attack the boating problem. First, it declared that the smaller pond was not a part of the main lake, although connected therewith by a narrow channel; also that, notwithstanding its area, it was the private property of the city, in which the general public had no rights.

In accordance with this decree, the commissioners ordered the removal of all boats and wharves from the smaller pond. Second, boating and fishing in the main lake was likewise prohibited, subject to a proviso: that, following formal application from a responsible person, the superintendent of the water works might, in his discretion, issue a limited period permit to such person and his household to go upon the lake with the exception of that portion within one-quarter mile of the intake. Each such applicant is required to sign an agreement that he will comply with certain regulations, which are set forth in detail.

Following defiance of these rules by the owner of the steamboat line, the superintendent of the works proceeded to remove his

boats and to demolish his wharves. It is a matter of special interest to note that, in the suit which resulted, the city's contention has been unequivocally upheld by the Court, it being ruled by the latter that the orders issued were entirely reasonable and proper in the interest of protecting the purity of the public water supply. While such a decision might be anticipated, as being in keeping with the present trend in such matters, yet, as many of you will realize, the result might have been somewhat different a generation ago.

Of course such drastic control of navigation is hardly feasible in the cases of the larger inter-township lakes, yet the Concord action goes to show what can be accomplished in those numerous instances where a body of water, although of sufficient area to bring it within the designation of a public pond, is, nevertheless, hardly more than adequate in size for the reasonable storage needs of a public system.

In the instances where we find the colon bacillus in our public supplies, it is present in nearly all cases as a result of pasturage of the watershed, drainage from cultivated land, or wash from highways. In a case recently coming up where the intake was in a roadside stream a mile below the lake outlet, the contamination of this brook by roadwash was shown to be so extensive, particularly at certain seasons, that the water company has been compelled, following an order, to extend its main back up to the lake.

Most of our superintendents now appreciate the desirability of controlling at least enough of the watershed to exclude pasturage of a nature or extent liable to cause contamination. As an example of what may happen, an experience with the Antrim supply may be cited. We were called upon during the course of an exceptionally dry season to investigate a sudden wholesale appearance of dead tadpoles in the water. The pond in question, without inlet and mainly fed by surface wash from the abrupt and rather limited watershed, is but sixteen acres in area. At that time the shed was quite extensively pastured, with no fencing, cattle having access to the pond at every point. The pond level was far below the top of the outlet dam. At one end, and extending well into the pond, there was discovered a regular barnyard wallow, odorous and liberally manure-besprinkled, and evidently

representing the daily drinking and wading place of numerous cattle. Examination of the water showed a vile condition, an interesting feature being the increased chlorine content, more than ten times the normal. As a result, this system was out of commission for domestic use for thirty days.

At the present time there are eight filter plants in New Hampshire. Those at Exeter, Berlin, Lebanon, and West Lebanon are of the mechanical type, while Somersworth, Dover, and Franklin have the slow sand variety. The eighth, of special type for deferrization of the Merrimack supply, has already been referred to. The principal function of the Dover filter, which is a standard, covered, two-bed construction, is also that of iron removal. The West Lebanon filter is for the removal of color from a reserve storage, and those at Berlin and Franklin are also requisitioned only at times when the regular source is insufficient and the river has to be resorted to. Hypochlorite is employed with both the latter as an auxiliary treatment, while at Somersworth the filtered water is subjected to disinfection by chlorine gas.

The use of hypochlorite or chlorine is now practiced, either continuously or as needed, at six plants, these being Berlin, Franklin, Laconia, Somersworth, Raymond, and Woodsville. Brief reference to the Somersworth system will be of interest. The source is the Salmon Falls River, which receives the sewage of a number of towns, besides a certain amount of industrial refuse. The single-bed filter, constructed in 1897, and said to be the second covered plant to be built in this country, is of the design of the original Lawrence structure. The area is one-half acre, and, as the daily consumption ranges from 450 000 to 600 000 gal., this means a rather low filter rate of approximately one million gallons per acre per day. This fact and the comparatively high level of five to six feet of water upon the filter, together with a uniformity coefficient for the sand of approximately three, probably explains the unusual working capacity of this filter between cleanings, it never having been the practice to scrape the surface oftener than twice in any one year.

Because of the limited storage, sufficient for no more than two days, filter-cleaning has always been a somewhat difficult proposition. The practice has been to get the standpipe full, then put on a large gang of men and push the job as rapidly as

possible. Obviously, the efficiency of the filter immediately following cleaning is extremely low, and, as an agency to be relied upon for the uniform and continuous purification of the comparatively bad raw water, it has proved somewhat of a delusion.

Early in 1913 a chlorine equipment was added to the system, this, again, being the second installation in this country to regularly employ chlorine gas in conjunction with a municipal water system. This treatment, which involves the use of three to four tenths parts of chlorine per million, has proved thoroughly successful. Instead of being a mere auxiliary to sand filtration, it is in this case — at least during certain periods — actually the mainstay of the purification treatment.

For a filtered water, that of the Somersworth system is relatively rather highly colored, running some forty to fifty parts per million. Already possessing the most expensive item of a color removal equipment, i. e., the filter, it must immediately occur to any engineer that the city is acting unwisely in failing to complete and get the full advantage of this equipment through the installation of means for applying coagulation.

The first plant in the state to use hypochlorite was that of the Laconia Water Works, this treatment being installed in 1912. The source is Lake Paugus, an arm of Winnepesaukee. Although chemically and physically this water is always of unusual excellence for a surface source, yet bacterially the results of examination were not always satisfactory, and because of certain unfavorable conditions, the adoption of a disinfection treatment was recommended by our department

A rather remarkable feature in connection with the Lakeport chlorination is the extremely small dosage required, due to the unusual natural purity of the source. Although it was originally planned to use from .20 to .25 parts of chlorine per million, it has been repeatedly demonstrated that as little as one tenth part, corresponding to as little as two and one-half pounds of bleach per million gallons, is ordinarily ample for the removal of all bacteria of intestinal origin and for 99 per cent. or more of the total bacterial count.

The Lakeport plant and the results achieved there in water sterilization form an excellent illustration of what can be done and should be done in the cases of very many of our New England

surface waters in order to place them upon a higher plane of safety. Very frequently there is no occasion for resorting to expensive filtration. Chlorination, preferably through the medium of chlorine gas, solves the problem. The writer has felt for some time that, as a final precaution,—as a comparatively inexpensive variety of insurance,—the application of a treatment of this character would be an excellent thing in the case of almost any of our surface supplies.

Since 1913 New Hampshire has had a law which provides in effect that before any new source of supply may be adopted, or any extensions or additions made of existent sources, an examination of such source by the state board of health shall be made, full plans submitted, and the approval of the state board secured. In our estimation, this is proving to be a very wise and beneficial law. During the last session this law was amended so as to give the state board of health special control of emergency intakes drawing from unapproved sources, also of industrial connections in the case of manufacturing plants having a secondary system of supply for fire protection. A feature of the law is that the existence of all such intakes and connections must be placed on record with the board. Already we have discovered a number of bad cases, where a highly polluted factory source was separated, in an emergency, from the regular public system merely by a single antiquated check-valve. In such cases we have required the installation of the Factory Mutual type of connection, involving two check-valves of special type placed in series. At the present time, at least, we are disposed to believe that, while such a connection does not afford the consumer absolutely perfect protection, yet it represents a decided improvement over the older type of connection and one that is apparently tolerably safe in most situations.

From the standpoint of health protection, our department has always felt considerable interest in the service pipe problem. It has become a fixed policy with the New Hampshire board to advise against the use of lead as a water-conducting medium in the case of private supplies, and it is probable that under the law cited, any further proposed installations of public character involving the use of lead pipe would not receive the sanction of the board. During the past fifteen years, as a result of numerous cases of lead-

poisoning arising, hundreds of these lead-conducted systems have been condemned.

Contrary to the common notion, the incrustation which forms in lead pipe is not an innocent coating of lime salts, but instead is a carbonate of lead, quite insoluble, it is true, in carbon dioxide-free water, yet very readily soluble as a highly poisonous compound in water carrying this gas in appreciable amount. For this reason we have found the amount of dissolved lead liable to considerable fluctuation, and that the results of analysis at any one time cannot be accepted as an altogether reliable criterion of what may be true at other times. Because of the fact that surface waters, containing as they do but slight amounts of carbon dioxide, have very little action, as a rule, upon lead; because of the difference in individual susceptibility; and because of the frequent extremely slow and insidious progress of lead-poisoning, practical water-works men are, it would appear, inclined to adopt a more or less skeptical attitude toward this question,— an attitude which is not justified by our actual knowledge of the subject.

Probably 90 per cent. of the replacements in the case of private systems are with galvanized iron. We have found that with ground waters carrying appreciable amounts of carbon dioxide there is a tendency to considerable solution of zinc, such amounts as 3, 4, and 5 parts per million being not unusual, while much more even is at times encountered. Although unfortunately there is very little clinical evidence as to the toxicity of minute amounts of zinc, yet there would seem to be no room for question that the daily ingestion of the amounts referred to must be, to say the least, objectionable. For that matter, there are certainly grounds for believing that even such a supposedly innocent and beneficial substance as iron is deleterious as a daily diet year in and year out, when the quantity of this metal present in the water is sufficient, as is sometimes the case, to impart a faint but noticeably astringent taste.

"What kind of pipe ought we to use?" has become a rather familiar inquiry. In view of the fact that the merits of cement-lined iron have for a long time appealed to the writer, he is especially interested to note the sentiment manifested in its favor at this time.

# FORESTRY IN RELATION TO PUBLIC WATER SUPPLIES.

BY PROF. J. W. TOUMEY, DIRECTOR SCHOOL OF FORESTRY, YALE UNIVERSITY, NEW HAVEN, CONN.

[*Read February 14, 1917.*]

I was very glad when your President sent me a letter, several days ago, asking me if I would address this body of men on the subject of forestry in its relation to the potable water supplies of New England. I wrote him that I would be pleased to do so, because there is no body of men that can undertake the practice of forestry with the reasonable expectation of economic success better than the men who control the drainage areas from which the potable water supplies of New England come.

Introductory to what I am going to say this afternoon, I would like to call your attention to what the forest condition was in New England at the time of the settlement of the country, and why it has come down to us in the condition that it is to-day.

When New England was first settled, the entire area was covered with virgin forest, with the exception of a few scattered places here and there where the Indians grew their corn and tobacco. The settlers who came into New England first cleared the woods from the valleys and the richer portions of the land. As settlement increased, they extended their clearings over the hills and the low mountain sides until they extended far beyond the area of what is strictly agricultural land; and seventy-five years ago there was more land in cultivation in southern New England than there is to-day.

It was necessary, it was sound economics, it was wise, to clear the land in the process of settlement, so far as it could be used for the production of agricultural products. But the work of utilizing the forest extended far beyond that. It went so far as to extend over large areas which were not agricultural. By repeated cuttings, by repeated burnings, the productive power of these non-agricultural lands was reduced, until to-day in many parts of New

England the more of this exhausted land a man owns, the poorer he is. There isn't any question in my mind but that the greatest economic problem that is before this country to-day, with our rapid increase in population, is the use of land.

Land is strictly of two kinds, and it serves three fundamental purposes, namely, to feed, clothe, and shelter man. Land is agricultural or it is forest land; it produces agricultural crops and it produces forest crops.

In October, 1913, the *Yale Review* published "Earth Hunger," the noteworthy essay by W. G. Sumner, the celebrated American economist. Professor Sumner states in this essay that earth hunger is becoming the wildest craving of modern nations. "They will shed their life blood to appease it. It gratifies national vanity and economic expansion both at once. No reasoning can arrest it and no arguments satisfy it." The truth of this statement by Sumner, published in 1913, is now being verified by the greatest spilling of human blood that the world has yet seen. The business of life as time goes on must center in getting more subsistence out of each acre of land, because this is the only way that each nation can support more people or support the same people as at present in a higher degree of comfort. How to get the maximum of the materials that feed, clothe, and shelter mankind out of the land is becoming essential with the passage of time. Increased production of materials from the land will, in the future, measure the capacity and power of the different nations.

With this brief introduction I want to call your attention directly to what you who have to deal with the potable water supply of New England can do and what you ought to do. You are accumulating, probably faster than many of you realize, when you take the whole of New England into consideration, vast areas of land. To-day every potable water supply company, every corporation which has to do with providing water for the public to drink, is concerned with the source of that water. You want to have pure water. That means that you have to control to a greater or less extent large bodies of land that surround your reservoirs. Some single cities already in the East own as much as twenty-five thousand acres of land; many own five thousand, eight thousand, and ten thousand acres. There are a great many cities and towns

in New England, and in the aggregate they own a very large amount of land.

Furthermore, this land for the most part is accessible to large communities that have need for wood. If you are going to accumulate large bodies of land of this character, it is absolutely necessary, in the economic development of the country, that you put that land to its best use consistent with a pure water supply. How can you use it? There is only one use that it can serve, and that is to grow timber. You cannot farm it, you cannot have people living upon it, you cannot have the source of the water supply contaminated. You must use it to grow timber.

This fact is already recognized by a great many people in New England. But there are men who say, " Is this a profitable undertaking? Isn't it pretty small potatoes for a water company to undertake the growing of timber? " I would say to you that if it were not necessary for you to own land, or from the fact of ownership put that land to its best economic use, it would be an unwise thing for you to purchase land to grow timber or to grow anything else. But so long as you must have the land, and so long as the area owned by you is very rapidly increasing, it must be put to an economic use or some day the public won't stand for it.

I could take you to scores of places I have visited abroad that illustrate in a very clear manner what this problem of forestry in connection with potable water supply means. The city of Vienna, with over a million and a half population, derives its water from a low rolling area of limestone hills, stretching almost from the gates of Vienna to the Austrian Alps. That area is covered with timber. The net annual return to the city from that forest is about six dollars net per acre. Those of you who have 10 000 acres of land in your watershed would be interested if you could get an annual revenue of $60 000 out of that item alone. You can't do it now, but some day you can. The small village of Forbach in Baden, in the Black Forest, derives a net annual revenue of $12 an acre from its forest, and has for a number of years, and will continue to do so for an indefinite period to come.

If that is possible in the settled communities of Europe, with our rapid increase in population it is just as sure that it is going

to be possible in this country. There is no question about it. It is in the future, however. But a corporation ought to look into the future and not be concerned solely with the things of to-day.

I presume that many of you gentlemen who have control of land look upon the possession of it as a necessary evil because you are not getting anything from it and, moreover, you can't see how you are going to get very much from it in the future. You haven't any trees on those areas that are worth anything, speaking in a comparative way, and that is the reason you aren't getting economic returns from them. You aren't going to get anything worth while if you are going to grow, or let grow by themselves, nothing but scrubby hardwoods. You can take to-day, or a forester can take to-day, any of those areas of mixed hardwood scrub and by the closest calculations that interest rates allow, he cannot figure out any profit in the long run, or but very little. The growth is too slow and there is too large a percentage of it which is unmerchantable. The thing is to convert those areas of hardwood culls into profitable stands of timber. You can't do this in one year, or in ten years, but you can do it in a hundred years. You should begin now.

New Haven County, one of the earliest settled counties in this country, — settled nearly three hundred years ago, — has to-day forty-six per cent. of the area of the county in wood. It has twenty per cent. more wood than it had seventy-five years ago. A careful survey was made six or seven years ago to ascertain what the owners were obtaining from these mixed stands of miscellaneous hardwoods, — uncared for and frequently burned, and aggregating about 85 000 acres, — and the average gross returns were between 50 cents and $1 an acre. You can readily see that these results indicate that there is not very much ahead in that kind of growth. You know very well that a savage will require one hundred acres of wilderness to obtain as much of the essentials of life as a civilized man will obtain from an acre of cultivated land. Wild woods require ten times the acreage to produce as much useful material as an acre of managed and cultivated woods, in the sense understood by a forester.

Now, if this is true, what are you going to do? You begin

to-day, to-morrow, next year, ten years from now, or at some time, to handle your land in a productive way; and I believe the sooner that you, who have charge of the watersheds from which the potable water of New England flows, get the point of view of improving the watershed from the standpoint of productive timber, the wiser you will be. You may not be in a position to do very much the first year. Forestry is a long-time proposition. It doesn't matter so much whether you begin this year, or whether you begin next year or the year after, or how much you do this year or how much you do next year, as it does to get the point of view of the direction in which you are going.

To point out in a general way what you can do, I call your attention to one water company that I am fairly well familiar with, that is, the New Haven Water Company. Fifteen years ago a portion of the area owned by this company, which owns between nine and ten thousand acres, was placed under management. Later, under the direction of the Yale School of Forestry, the remainder was placed under management. The company now has a forestry department which is concerned with the growing of timber and the taking care of timber, and nothing else. The work started by having a careful preliminary report made of all the watersheds owned by the company. I believe that this is the first thing that any one or any water company who is going to undertake this forestry proposition has to do. The report must not be made by a boy; it must be simple, it must be clear-cut, it must be direct, it must show what you have in the way of timber and wood, and what the quality of the land is.

I haven't the preliminary report which was made to the New Haven Water Company, but I have here a few copies of a preliminary report made of a forest property that is owned by the Yale School of Forestry at Keene, N. H. This will show you something of what ought to be embraced in such a report, when made for a water company or for any other corporation or any other body of men that have big tracts of land that they want to put under management and want to handle from this long-range forestry point of view. If any of you will send me a letter, addressed to the Yale School of Forestry, New Haven, Conn., I will be very glad to send you one of these reports.

From the preliminary report and later studies, a working plan is made under which it is proposed that the property will be handled or managed. I have here the first working plan which was made for the New Haven Water Company, and I believe it is the first working plan published by a water company in this country. I would also be glad to send to you gentlemen copies of this working plan.

What has resulted from the work of the New Haven Water Company? The lands which they own are miscellaneous in character, poor farm lands for the most part, with patches of coppice timber here and there, and open meadows. I presume it is the same character of country that most of you have in your own watersheds. What are you doing with your land? The New Haven Water Company is doing three things:

First. Planting conifers on all open land — and there are thousand of acres of such land.

Second. The lumber on brush-covered areas is permitted to grow until it is large enough to cut for fuel, when it will be cut and the areas planted with conifers. Where areas are covered with scrub, we find that we can't plant satisfactorily, and the cost of clearing is prohibitive. If they are permitted to grow until the growth is big enough to cut for fuel, it will pay for the cost of clearing. After cutting, such areas are planted with conifers.

Third. The areas already in good hardwood timber and in stands of hardwood and hemlock are thinned periodically and kept in healthy condition. Improvement thinnings are made as early as the material cut will pay the cost of removal.

Observe in this working plan that everything is hedged in by the question of cost,—and it has to be so. The possibility of thinnings is determined by costs; cuttings are made when justified by market conditions.

All of the over-mature timber, all of the wolf trees, all of the large material which isn't improving, is cut as rapidly as practicable.

The hardwoods at the tops of ridges and wherever else the forest serves its greatest protective purpose are maintained in the uneven-age form. I mean by this that the land is not cut clear. The mature trees are taken out a few at a time.

What is the long-vision point of view in this work? The aim is, by handling the property under modern forestry methods, to bring every acre to its highest productivity; that is, to bring each acre into a condition under which it will produce the most material and produce material of a quality which will fetch the highest price. We don't want fuel wood; we want something better than fuel wood.

You can readily imagine that a company starting with old stands of wood which have been burned here and there, woods that have been neglected for a hundred or two hundred years, will find it a tremendous job to change from the method under which they have been going downhill to a method which looks upward and which will ultimately result in developing a satisfactory forest.

The New Haven Water Company in the last nine years, since accurate data have been kept, has sold about $37 000 worth of wood products. What has it done with the money? All of its forestry work, all of its forest improvements, all of its forest help, has been paid for out of it, and there is to-day credited to the Forestry Account some eight or nine thousand dollars. The forest has been turned from the condition in which it formerly was into the new order of progressive development. Over $13 000 have been spent in planting alone, and it is the fixed policy of this company to plant approximately 250 000 trees a year. The planting is done at a cost of about $11 an acre. The first plantations made fifteen years ago are so large one can well get lost in them. The planting has been uniformly successful.

If you gentlemen are going to spend money in improving your watersheds from the standpoint of forestry, you must have a reasonable assurance of getting something out of them in the future. The trees which are always going to fetch the best prices when grown in large numbers are soft woods. This is so in Europe. To-day in Europe, after centuries of forest management, hardwood stands are continually decreasing and soft-wood stands increasing. I have never seen a hardwood stand in Europe which produced anything like the revenue per acre that stands of soft wood produce. A soft-wood forest may produce an annual net revenue of $12 an acre in some parts of Europe; this is never possible with a hardwood forest. You can figure out in New England but very little

profit from hardwood. The growth is slow and the amount of salable material is comparatively low.

Near the property of the School of Forestry at Keene, N. H., a Mr. Ellis two years ago sold the second-growth pine on twenty-two acres when sixty-three years old, — no better than what you should expect on equally good land if you planted pine 6 by 6 feet apart in New England, — for $15 000.

In 1871, also near to the property of the School of Forestry at Keene, an old gentleman one spring took a dishpan and gathered some white pine trees. He planted them eight feet apart in each direction on a precipitous slope near his home, on land worth less than $10 an acre. He died some three years ago and that property of less than three acres was sold for $1 000.

This isn't a fairy story; it is what we can expect. Some day timber is going to be worth more than it is to-day. Those who plant to-day are reasonably certain that they are going to get more for the timber when it is grown than the market will give them to-day for the same class of timber. The trend in the long run is going to be uphill for timber values, although it is going to be fairly slight until our large surplus supply of virgin timber is exhausted.

I want to say to you, I want to leave these words with you, if you are thinking of practicing forestry on the properties that you have in charge, — take it up in a serious way. I believe that a water company should consider forest esthetics as secondary to timber production. If you get a good productive forest, it is just as beautiful a forest as you can have. Every forest that is owned by a municipal water company abroad is handled from the standpoint of the economic production of wood. Those forests are traversed by thousands of people every year. In the beautiful *Wienerwald* near Vienna, there is easy and rapid transportation by train and automobile, and there are inns to accommodate the people who go there for recreational purposes, yet the city is getting very large annual returns from the timber. The forests are handled from the standpoint of timber production, from the standpoint of making the land productive.

Those of you who have not undertaken as yet the handling of your forest property from the standpoint of timber production

should first make a careful examination of your property. Have it made by some one competent to make it and give you the information necessary to show you what the possibilities are. This report on the Keene forest is suggestive of what a report ought to show.

After the preliminary report has been made by an experienced and competent forester, there should be a man in your company's organization directly responsible for the forestry work. He should give all or a part of his time to the carrying out of the work planned by the forester; and. if the property is large enough so that the receipts will justify it, you should have permanently at your command the services of a consulting forester, just as the New Haven Water Company has to-day, who looks into the future, knits the various projects together, and points out in his working plan how much is to be done each year, and how the material is to be disposed of. The cutting of timber, the selling of timber, the planting of trees, and the wise handling of a forest property require special knowledge. You can't leave these to any one whom you chance to employ.

You should have an inventory of your property. I mean by this that a map or maps should be prepared upon which are located the areas of woodland. The maps should be on a reasonably large scale, on which the woods are classified by types and stands, and where there is a record of the amount of wood of various classes in each unit.

On the basis of the maps and on the basis of the figures that have been obtained in the inventory of the property, the forester is able to draw up a definite working plan. This definite working plan should be adhered to so far as possible until it is revised.

## Discussion.

John Kelso, Esq.* From time to time the water rates in Providence have been reduced when the earnings were in excess of the amount required to take care of the principal and interest on the bonds issued up to that time on the plant. Finally, the Council decided that it would set aside this particular surplus towards

* Of the Water Supply Commission, Providence, R. I.

a depreciation and extension fund instead of reducing the rates, having in mind that it would be well to have such a fund in order to buy up odd pieces of land that might be obtained. This action was very gratifying to the Committee on Increased Water Supply, as it gave them quite a sum of money for its preliminary investigations, without exciting unduly those of our citizens who would be inclined to profit by speculating in properties which it was necessary for the Board to secure to construct our new reservoir. The resolution of the City Council is as follows:

"SEC. 60. A special fund to be known as 'Water Works Depreciation and Extension Fund' is hereby established for the following purposes. The city auditor, annually, on the last business day of each fiscal year, shall determine what amount of money is equal to three per centum of the valuation of the water works, as shown by the city auditor's annual report for the last preceding year, after deducting from said valuation the value of the land owned by the city and included in the water works, and shall forthwith cause such amount of money to be paid to the board of commissioners of sinking funds and charged to 'water rents.' Said board shall hold said fund and all payments therefor and earnings thereof as a separate fund of the city, with full power to control, manage, invest and reinvest the same, and said board shall pay to the city treasurer such portions of said fund as the city council shall from time to time direct. Said fund shall be used and expended under the direction of the commissioner of public works, only as ordered by the city council, for replacing buildings, or machinery included in the water works which may become unserviceable, for any expense of extending the water works system, for the purpose of increasing or improving the source of supply, and for replacing such other unserviceable property included in the water works as said city council may direct."

I would like to ask Professor Toumey whether he thinks it would be better to spend the money in buying parcels of land or in planting trees.

PROFESSOR TOUMEY. I should say that, in most instances where the amount of money available for the improvement of the watershed is small, it is a better policy to expend it in the purchase of parcels of land instead of planting trees. It is the best policy to acquire a reasonable amount of land first. The improvement of the forest can be begun later. The watershed should be

developed as a forest and not as a park. Personally, I am sorry that the term "outlying city park" ever came into use in this country. In my judgment, there isn't any such thing; it is an outlying forest. Who wants to go into the country to see an open park? An open park is well enough in the city, but when we go into the country, take our lunch basket and go for a day, we want to go into the wild woods. The woodland protecting potable water should not be called a park; it is a forest, — and it ought to be a forest, because a forest can best serve for the kind of recreation that is needed by the public and, furthermore, it can be made a source of revenue.

The main thing to consider in developing the woodland owned in connection with potable water supply is the right kind of a start. Have the right point of view in beginning the work tending toward the development of the forest. If we start with the right point of view, we are justified in planting and in other development work as rapidly as funds are available. We should begin right. A large property demands a well-worked-out preliminary report in order to know what we have. As the work progresses, a working plan should be made for the property.

President Saville. Among the many far-sighted plans the carrying out of which has made the Metropolitan System a model, has been that in connection with forestry work on the Wachusett System.

Mr. Hiram A. Miller.* When we started on the Metropolitan work, we got somebody from Washington, whose name I do not now recollect, to go over the territory, some five thousand acres, and make out a preliminary report and something in the nature of a working plan, — although it was hardly definite enough to be considered a working plan. We took that up, and the first thing we did was to establish some pine-tree nurseries, and we have had three different nurseries at one time, although one of them was subsequently abandoned. Of course we made some mistakes, because we were rather green at the work twenty years ago, and there wasn't so much known about forestry in this country then as there is to-day.

In our first experiments we planted, alternately, hard maples

* Consulting Engineer, Boston, Mass.

and white pines. I think they were four feet apart, the idea being that we would cut off the maples after they got large enough for cord wood, which was the advice we received at that time. Then we thinned over quite a lot of the tract and divided it up into parcels of thirty to sixty acres as the topography of the tract would permit, by roads, so that we would have a sort of a fire guard, and also access to all of the land, so that we could get around each one of the tracts by these roads, which were decently passable, fairly good woods roads. On the outside tracts, where we came in contact with land which the Metropolitan Board did not own, we cleared a fire guard one hundred feet wide. The thinning hadn't been carried to a very great extent when I left. Some of the tracts were improved in that way, leaving the better timber growing, with very little of what could be called mature forest on the tract, because as soon as it got so that the farmers could sell the wood for a small sum they always sold it, so that there was very little on the whole tract which was of any value except for cord wood, and, of course, a very large proportion of it was brush. We tried planting some in the brush, but we found, as Professor Toumey has said, that that didn't work well. We planted some areas and then would cut the brush around the pines as it grew up, and try to give the pine trees a chance to grow, but we didn't succeed very well. It cost too much. I left the work with Mr. Allardice when I came away.

MR. E. R. B. ALLARDICE.* During the past twenty years, the establishment of a forest cover over the lands bordering the Wachusett Reservoir of the Metropolitan Water Works of Massachusetts has been actively prosecuted with the fourfold end in view of —

*First*, preserving and increasing the purity of the water supply.

*Second*, conserving the run-off in the spring months.

*Third*, utilizing for commercial purposes what would otherwise become a wild and waste tract.

*Fourth*, establishing what has proven to be a sanctuary where numerous wild animals and birds enjoy the protection which such a reservation provides, and where they can, with a certain degree of safety, propagate.

* Superintendent Wachusett Department, Metropolitan Water Works, Mass.

The watershed area tributary to this reservoir covers about 118 square miles, of which about 7 square miles — bordering on the immediate shore of the reservoir and extending along the principal tributary streams — are owned by the Commonwealth and controlled by the Metropolitan Water and Sewerage Board. This area of about 7 square miles has been developed along the lines of modern forestry from a pre-arranged plan whereby the land could be put to its most economic use without affecting, to the slightest degree, the paramount purpose of securing a pure water supply. Those portions of the reservation, consisting of arable, pasture, and light sprout land, have been planted to native white pines, making a self-perpetuating forest which would ultimately provide a complete ground cover, requiring no artificial fertilizing or disturbing of the soil, and which would protect the waters of the basin from the direct contamination of manurial matters and soil washed from adjacent farms during heavy freshets of spring floods. The white pine was selected because of its almost universal adaptability to the various kinds of land and growth to be treated, its freedom from leaves, its rising value in the lumber market, and the ease, low cost, and its then comparative certainty of raising to maturity.

Thus far, some 1 425 acres have been planted with coniferous trees — mostly native white pine — using some million and three-fourth seedlings, the greater proportion of which have been raised in nurseries established and maintained for this purpose, though of late about one half of the seedlings set out have been furnished by the State Forestry Department. The reservation includes some 1 690 acres grown to deciduous trees of many varieties, — mostly chestnut, oak, and maple, — which are from time to time being thinned and improved to increase their ultimate commercial value.

In addition to these two general divisions of the reservation, there are 870 acres on the back slopes of the dikes, and numerous vistas which are preserved as grass land and which it is planned not to forest.

There remain to be planted about 585 acres of land, the seedlings for which are being raised in our nurseries.

Because of the damage done to the white pine by the pine-tree

weevil, and the threatening danger from the blister rust, our present plans include the use of the red pine on about a fifty per cent. base, they being (as far as is known) immune from both of these destructive elements.

The benefits to be derived from the presence of these large pine stands — where the flood run-off in the spring is materially lessened and the melting of the snow, continued to late in the season — are apparent even now, where the trees are from fifteen to eighteen years old.

For further protecting the waters of the reservoir, a continuous compact screen of arbor vitae has been set out along thirty-two miles of the shore, to prevent foliage from being blown into the water. Two rows of trees two feet apart, with trees three feet apart in rows, were set out, and to-day there are long stretches where they are from eight to twelve feet high, forming a solid bank against which the dead foliage from the hard woods is blown. This screen has not, however, grown up uniformly, for, on the exposed location, along the southerly shore, the wind and ice storms have seriously hindered their growth, if not completely killed them.

The lower three miles of the Wachusett Aqueduct is of the open-channel type, with marginal strips of land varying in width from fifty to five hundred feet, which have, of late years, been planted to native white pine. At some places, where the marginal lands are low and swampy and not adapted to the white pine, it is proposed to set out American tamarack trees.

When the policy of making forestry work a part of a water-works system is adopted, numerous additional obligations are automatically accepted. For instance, the protection of the forests from destruction by fire and the ravages of the seemingly never-ending plagues which are sources of considerable expense. It is our policy to patrol the reservation on Sundays and holidays through the dangerous seasons of the year. The patrolmen carry shovels and fire extinguishers, while a forty-horse-power motor-driven power sprayer and pump is kept in readiness. Several gratifying experiences have proved the value of this machine as a fire fighter. Then, again, to properly protect the forests from the ravages of the numerous destructive elements which have

been handed us during the past few years requires the expenditure of considerable money if the full benefits from these forestry operations are to be realized. Our forestry operations are carried on by the regular water-works maintenance forces, augmented from time to time during the planting seasons.

The major portion of the watershed area is not owned or in any way controlled by the board, so as to be available for forestry operations, but there is evidenced on the part of a few of the more aggressive farmers a desire to follow our example in utilizing their waste lands. Undoubtedly this practice will increase from time to time, especially when we begin to get some financial returns from the investment. As this work on the part of the farmer is extended, the benefits derived from our operations should be much greater and the conservation of the run-off and quality of the water increased in the same proportion.

PRESIDENT SAVILLE. Mr. Allardice, if you were going to start over again in forestry work, would you put in your own nurseries or buy your stock?

MR. ALLARDICE. I am very thoroughly convinced, from the success that we have had with our nurseries, that we have been wise in maintaining our own. At the present time we have two large nurseries with about 400 000 pine trees, half of which will be planted the coming spring.

PROFESSOR TOUMEY. What does your stock cost you?

MR. ALLARDICE. From published figures* of a 30-acre lot, planted 6 by 6, using in the neighborhood of 36 000 trees, our stock cost us $205. Those trees, as a rule, are three years old.

MR. WILLIAM F. SULLIVAN.† Professor Toumey likened his talk to a vision. I belive it was sound advice, common sense. Forestry bears an especially close relationship to water works, for do not most water works have some land suitable for forestry? Then why not develop it, and eventually get a crop, the kind of a crop that is feasible from this kind of property?

The professor also spoke of the low price of oak and scrub hard woods. I agree with him that the money received for this kind of cord wood has in the past barely paid for the cost of producing

* JOURNAL N. E. W. W. A., XXX, 83.

† Engineer and Superintendent Pennichuck Water Works, Nashua, N. H.

and delivering. With the high price of coal and the difficulty in obtaining it, I think to-day is a good time for owners of scrub oak and inferior species of hard wood to cut it out and sell it for fuel, also for water works to profit by the use of it for pumping fuel in place of coal. So, I say, cut it out now and get the advantage of the present fuel situation.

Occasionally there were men, years ago, connected with water works who had long vision. These men procured land around their water supplies. This was before scientific forestry attracted the attention of woodlot owners. These men purchased barren lands, scrub woodlots and sometimes timbered land. This land was gradually worked, so that to-day around many water supplies there are stands of merchantable timber. When these men first took up forestry, it was before much thought was given to the conservation of natural resources, or much attention paid to the pollution of streams. They did the reasonable and, in the light of present-day practice, the sensible thing, -- they developed their woodlands. And to-day there may be realized in some places as much per acre as the professor stated was realized on those timber tracts near Keene, N. H.

Is it not a splendid thing for any community to have its water works develop and reforest the lands under its control, so that in time there will be public or semi-public forests for the public use and for recreation purposes under proper regulation? These reservations, either in parts or in the aggregate, will add to the beauty, the grandeur, and to the wealth of the state.

I agree with the professor that the so-called outlying or suburban parks do not seem to entirely satisfy the desire of the public for recreation purposes, for it is well-kept forests and woodlands which thrill one as he wanders and roams at will in the great out-of-doors.

Large water works like the Metropolitan, of Massachusetts, which has been spoken of here to-day by Mr. Allardice, nowadays have an expert and scientific organization. In addition, this organization has a yearly appropriation for improvements and development work in forestry. The Metropolitan and other water works are doing good work. One has only to visualize the Metropolitan land areas of years ago and then look at the same

territory to-day. This work will surely pay, not only in dividends but in pleasure to the inhabitants. The work which is being done under the supervision of Mr. Allardice will be worth to the state in scenic values alone more than it costs.

In small water works, with few men and limited funds, it is an excellent and paying work to have on hand and to do. At spare times, put what men you have on hand in the woods under intelligent supervision. In the winter time it will enable you to have a crew on hand who are earning their keep.

At the present time our company is logging and sawing timber which is merchantable. This is possible with us to-day because of the foresight of the men of several generations ago. Speaking of pine nurseries, in many instances there is no need of nurseries. The older stands of pine, with their "seeders," furnish natural reproduction nurseries in which there are hundreds of thousands of saplings suitable for transplants. A water works may during slack periods — or even sometimes between jobs — send a few men into the woods and set out thousands of these small trees.

It is a distinct asset to a water supply to have surrounding its ponds, lakes, and streams beautiful green trees, summer and winter.

Discussing the moth pests, a few years ago we were all much disturbed about the brown-tail and gypsy moths. We, like others, endeavored to control them. Some of our neighbors showed an unwillingness to do their part. The result was that we gradually relaxed our vigilance, and to-day it seems as if these pests after reaching their height are on the wane, have reached sort of a normal level where natural agencies are holding them in check. The depredations of these pests have not been as destructive as it was first thought.

To-day there are not as many fires in the woods as formerly. The public has been educated and cautioned. Willful or careless individuals have been penalized for setting fires. Hunters and fishermen are coöperating with the authorities and with the owners of woodlands, in the prevention and detection of forest fires.

At the present time, a company is being formed, with headquarters at Berlin, N. H., for the purpose of insuring standing timber. There is to be a meeting in Boston, next month, of large and small

timber-lot owners, to complete the organization. Application for a charter for this Standing Timber Insurance Company has been made in the state of New Hampshire. I understand at the present time there are over thirty fire protective associations in the United States. These associations, with state and federal forestry departments, assisted by the towns, railroads, and the public generally, mean the elimination and prevention to a large extent of fire wastes in woodlands.

"A long pull and a steady pull" by the individual, the water works, the state, and nation, in improving, developing, reforesting, and protecting their properties, means greater timber growth which will in future years stabilize the yield and furnish wood for the demands. It is also the opinion of many that reforestation and care of woodlands will, when the forests are full grown, show a substantial return on the investment.

MR. PATRICK GEAR.* We started in Holyoke, some fourteen years ago, I guess, with about 2 500 acres of land that was covered with a lot of dead wood, crooked limbs, and broken trees and underbrush, and we cleaned it up. Like Mr. Sullivan, we had nothing for our men to do in the winter, and we wanted to keep them, so we put them into the woods. They cut out all the broken trees which were there, and got the hardwood out of the way, and now we don't have as many fires as we used to have.

We planted five or ten thousand white pines every year. We had trouble with our trees, a few years ago, and I sent up to Amherst College and got a professor to come down. He went all over the trees, spent a couple of days, and he found some kind of disease, which I think he called weevil. He wrote out a prescription for me which I could make up out of soap and kerosene oil, to spray the trees with. I bought a spraying machine and put two men out spraying the trees. So as to be satisfied that he was all right and that the trees would come out right, I left one corner which I didn't spray at all, and they are all alike this year, all good and healthy. The white pine blister they talk a good deal about, we haven't found yet.

PROFESSOR TOUMEY. I don't want to be put in the same position as the man who gave you advice about spraying your trees;

* Superintendent of Water Works, Holyoke, Mass.

but what you have said demonstrates one thing to my mind which is interesting. Trees have always grown, and they are going to grow. They are not going to disappear from the face of the earth. The thing we want to do is to have confidence and go ahead and plant trees. I don't believe that the white pine blister rust is going to wipe out white pines. I don't know just what it will do yet—nobody knows. It may be serious, we can't tell, but I would not stop work. I would do this, however, if I were going to plant white pine this spring — I would plant red pine in alternate rows with it. Then, if in later thinnings we find the white pine all right, we can cut out the red pine and bring the white pine to maturity the same as if we had planted all white pine.

MR. FRANK WINSOR.* I did not come prepared to discuss this subject, but will say a few words relative to reforestation of marginal areas around the Kensico reservoir which forms a part of the Catskill water supply system for New York City. This reservoir is about twenty-six miles north of the Grand Central Station, and has recently been filled, there being a marginal area of about 2 500 acres around it upon which extensive work in reforestation was carried on under my general direction from about 1910 to 1915, at which time the greater part of the work was nearing completion. The 2 500 acres was divided into arable, pasture, brush, and wood land, the latter with a considerable percentage of chestnut growth which became worthless on account of infection and was cleared under a contract, the City of New York paying $11 900 for the clearing. The area, cleared of chestnut growth, amounted to about 750 acres having considerable chestnut upon it and 270 acres with sparse growth, and the contractor was entitled to the salvage from his operations as well as to his contract price.

In the early part of the work, underplanting was done on some of the more sparsely wooded areas, but as a general rule it was finally concluded to be inadvisable and to generally limit the work on land having timber growth worthy of preservation to improvement clearing. The greatest trouble experienced, and the greatest that will probably be experienced in any locality, is from fire. As long as irresponsible people are permitted to roam at will

* Chief Engineer, Water Supply Board, Providence, R. I.

through such reservations, smoking pipes, cigarettes, etc., there does not appear to be any way to prevent fires, and in grass land which has been planted with small trees it is very difficult to prevent such fires from doing great damage. Cleared land is generally planted with about 1 200 trees to the acre, — that is, about 6 ft. by 6 ft. With three- or four-year-old transplants, there will be required from three to five years additional growth before the trees are sufficiently high to be seen above the grass in the summer. It is impracticable to cut the grass and avoid injury to the trees, and in the dry weather of the late summer and fall it becomes a tinder box, and if a fire starts in it — even with a force to fight it near at hand — it will generally burn over a considerable area before it can be extinguished, thus ruining in a few moments large areas which may represent several years of growth of the trees planted thereon. While the fire hazard will always remain, it undoubtedly diminishes considerably after the trees reach a size sufficient to choke out the undergrowth. There is great need of more rigorous laws regulating trespassing, hunting, smoking, etc., as a protection for such reservations against fire. The protection around Kensico reservoir was undoubtedly greater than has obtained in almost any other area where such work has been undertaken, as the Board of Water Supply had a police force around this reservoir in addition to a large force of men in the employ of the city and of contractors, notwithstanding which a number of fires occurred which destroyed the results of several years' work. The experience at Kensico might reasonably be expected to be repeated on any reservation within, say, twenty miles of any large city in New England. On the reservation of the Metropolitan Water Works around the Wachusett reservoir, I understand there have been several disastrous fires notwithstanding the greatest care and a most thorough organization to combat fires.

Fire is by no means the only enemy to reforestation, as almost every tree planted brings some kind of a pest with it, as, for instance, the weevil and blister rust. I have somewhat the same confidence that Professor Toumey has that trees will always grow, but it is most exasperating to plant white pine, for instance, and have it virtually ruined by the weevil before this pest can be

arrested. The trees which appear to be the most successful from the standpoint of rapid growth, although probably not from the standpoint of commercial value, are the Scotch and Austrian pines. While these may be looked upon somewhat as weeds in the conifer group, they grow very rapidly, and for reforestation, which is not primarily perhaps for revenue, they are in many ways preferable to the white pine. The red pines, while slower in growth, are apparently well adapted, as are the white pines, to planting in this locality.

The above discussion is based primarily upon reforestation with conifers, which appear to offer the best promise of satisfactory results in this section of the country. The problem of taking care of the growth which now exists is, however, a serious one. The chestnuts have already disappeared in some sections, and it seems to be a question whether they may not be doomed in New England.

In the reservation for the Scituate reservoir for the new water supply for the city of Providence, there is a marginal area of over 7 000 acres, the disposition of which has not yet been decided upon. A considerable percentage of the growth upon this area is chestnut, which does not generally appear to be badly infected, but the permanence of which from experience elsewhere — notably in Westchester County, New York, where during a period of between five and ten years it entirely disappeared — is very much in doubt. Purely as a commercial proposition, taking into consideration the danger from fire and the difficulty of insuring proper maintenance during a long term of years, there probably is not sufficient commercial justification on the part of the city for attempting the reforestation of these areas. Looking at it, however, from the standpoint which Professor Toumey has so ably presented, it would seem perhaps that in this instance some work of this kind might reasonably be expected, particularly from a municipality. It does not, however, appear to me as being wise to attempt such work until the large forces of the contractors engaged upon construction are through with their work, and until more stringent laws than are upon the statute books to-day are passed, to control access to these areas and to minimize danger from fire.

# BREAKS IN WATER MAINS.

BY S. E. KILLAM, SUPERINTENDENT PIPE LINES AND RESERVOIRS, METROPOLITAN WATER WORKS, BOSTON, MASS.

[*Read September 14, 1916.*]

Breaks in water mains, their causes, and means of preventing same, is a subject which is growing in interest to water-works officials throughout the United States, especially officials responsible for the supplies to thickly populated districts. The fact that it is always unknown when one of these breaks will occur is acknowledged by all engineers and superintendents having responsible charge of the water supplies as the most trying part of the maintenance of the water-works system.

The purpose of this paper is to give an account of the breaks which have occurred in connection with the supply of water to Boston, Mass., and the surrounding towns, known as the Metropolitan Water District, since the works were put in operation, January 1, 1898.

The Metropolitan Water District was created by an act of the state legislature in 1895 and now includes the following cities and towns: Boston, Chelsea, Everett, Malden, Medford, Melrose, Newton, Quincy, Revere, Somerville, Arlington, Belmont, Lexington, Milton, Nahant, Stoneham, Swampscott, Watertown, and Winthrop, — in all ten cities and nine towns. All of these, with the exception of Swampscott, are within ten miles of the State House, and all, with the exception of the city of Newton, are supplied with water from the Metropolitan works.

The works are under a commission of three appointed by the governor, known as the Metropolitan Water and Sewerage Board. At present the board consists of Henry P. Walcott, M.D., chairman; Edward A. McLaughlin, and Thomas E. Dwyer, with William E. Foss, chief engineer of water works.

Under the general act of 1895 the board was required to take certain existing works from the city of Boston. Since that time,

other existing works have been taken from the city of Boston, and the town of Swampscott, until at the present time there are 23.67 miles of mains, varying in size from 10 in. to 48 in. in diameter, that were laid from 1848 to 1897. The remainder of the works of the distribution system, amounting to 98.57 miles, have been laid since 1896 under the direction of this board.

The area of the Metropolitan Water District is 174.8 sq. miles, and the population as supplied, July 1, 1916, is estimated as 1 190-220.

After careful consideration of the subject, cast-iron pipe was adopted as the material for the use of all supply mains, and its use has been continued since. It is not the writer's intention to enter into a discussion of the merits or demerits of cast iron and steel as the material to be used for supply mains, but in passing desires to quote from the late Dexter Brackett's statement made before this Association on January 11, 1899, relative to the reason for adopting cast-iron pipe for the Metropolitan system.*

"During the past few years, pipes made from steel plates from one quarter to three eighths of an inch in thickness have, as you all know, been used to a considerable extent for mains of large size, instances of which will be brought to your attention this afternoon. The advisability of using this class of pipe for our work was carefully considered, as many of our mains were to be of large size. The thinness of the metal in the steel pipes renders the length of life of the pipe very much dependent upon the ability of the coating to prevent corrosion of the iron, and where pipes are to be laid in public streets, as ours were to be, and the coating constantly exposed to injury on account of public work of various kinds, I do not think it would be possible to protect the coating from damage, except at a very great cost. If the coating is not thoroughly protected from injury, there is, to my mind, a serious doubt as to whether it is advisable to use so thin a material.

"As you know, Boston and vicinity is not noted for the regularity of street lines, and the frequent angles required in the pipe lines to conform to the changes in direction, both horizontal and vertical, many of which, due to underground objects, were only discovered when the trenches were opened, would have delayed the work and increased its cost. It would also have been impracticable to have left the pipes exposed in the streets for any considerable distance in order to apply a water-pressure test,

* Journal N. E. W. W. A., *13*, 325.

which is absolutely necessary for riveted pipes. For this, and perhaps some minor reasons, it was decided to use cast iron as a material for our pipe."

Water is distributed to the several cities and towns through 122.22 miles of pipes from 60 in. to 10 in. in diameter. Connected with these mains there are 516 valves for controlling the flow of the water, and 59 Venturi meters of sizes varying from 6 in. to 48 in., by means of which a continuous record is kept of the quantity of water used in each of the eighteen municipalities supplied with water.

With the exception of a 30-in. wrought-iron, cement-lined pipe line, 11 200 ft. long, a 10-in. calomine pipe line 3 140 ft. long, and a few short lengths of steel pipe, all the distributing pipes belonging to the Metropolitan Works are made of cast iron.

The distribution system in the several cities and towns which are supplied with water from the Metropolitan Works contain 1 732.85 miles of pipe, 176 236 services, and 16 928 fire hydrants.

Every precaution was taken in the construction of the works to see that the pipes were properly inspected as to quality of material, workmanship, and coating at the foundry. The pipes were again inspected as they were delivered at the various pipe yards for imperfections and cracks. The pipe lines were laid under the direction of engineers and inspectors especially qualified for this work. Instructions were given to see that the trench was properly excavated, especially in a rock cut, where there is great danger of breaks occurring if all projecting points of the rock are not removed to a sufficient depth to allow a slight settlement of the pipe after it has been laid. The table on the following page is a list of breaks which have occurred on the Metropolitan Works.

Of the twenty-five breaks that have occurred on the Metropolitan Water Works system since January 1, 1898, seven have been on pipes of existing works that were taken as part of the system. Thirteen of these breaks were due to settlement of the pipe on to a rigid support which supported the pipe at only one point. Five breaks were due to cracked pipe, two to blasting, one to a water hammer caused by a pressure regulator, one to a spud of a dredge being dropped on to the pipe, one to a dredge pulling a pipe apart, one to a blow-out in a cement line, and one, cause unknown.

| Date of Break. | Diam. of Pipe. Inches. | Location. | Reported Cause of Break. |
|---|---|---|---|
| Nov. 14, 1899. | 36 | Middlesex Fells Parkway, Malden. | Settlement on a bowlder. |
| Mar. 30, 1900. | 20 | High St., Everett. | Water hammer from pressure regulator. |
| Oct. 1, 1900. | 48 | Boylston St., Brookline. | Blasting. |
| Sept. 20, 1901. | 24 | Heath St., Somerville. | Settlement on ledge. |
| Nov. 29, 1901. | 24 | Main St., Somerville. | Cracked pipe. |
| Aug. 21, 1902. | 30 | Main St., Malden. | Settlement on ledge. |
| Feb. 25, 1904. | 30 | Chestnut Hill, Brighton. | Settlement on end of timber. |
| Oct. 16, 1904. | 16 | Winthrop Ave., Revere. | Cracked pipe. |
| Oct. 28, 1905. | 36 | Chestnut Hill, Brighton. | Settlement on end of timber. |
| Feb. 11, 1906. | 6 | Chestnut Hill, Brighton. | Cracked pipe. |
| Apr. 18, 1906. | 48 | Chestnut Hill, Brighton. | Settlement on aqueduct. |
| Nov. 1, 1906. | 48 | Washington St., Melrose. | Blasting. |
| Feb. 5, 1908. | 36 | Morton St., West Roxbury. | Settlement on a bowlder. |
| June 13, 1908. | 24 | Broadway, Somerville. | Settlement on ledge. |
| May 25, 1909. | 48 | Franklin St., Allston. | Cracked pipe. |
| Dec. 24, 1909. | 48 | Harvard Sq., Cambridge. | Settlement on electric conduit. |
| Feb. 13, 1912. | 24 | Adams St., Milton. | Settlement on sewer. |
| July 19, 1913. | 24 | Broadway, Chelsea. | Cracked pipe due to electrolysis. |
| Nov. 18, 1913. | 24 | Temple St., Somerville. | Settlement on ledge. |
| Dec. 4, 1913. | 48 | Clinton Road, Brookline. | Unknown. |
| Oct. 13, 1914. | 36 | Mystic River, Medford. | Spud from dredge. |
| Aug. 16, 1915. | 12 | Neponset River, Hyde Park. | Flexible joint pulled apart. |
| Nov. 6, 1915. | 48 | Commonwealth Avenue, Newton. | Settlement on ledge. |
| Nov. 8, 1915. | 6 | Mystic Station, Somerville. | Cement pipe, side blew out. |
| Apr. 23, 1916. | 16 | Fox Hill Bridge, Lynn. | Settlement on abutment. |

The above table shows that thirteen of the breaks have been probably due to a slight settlement of the cast-iron pipe on to something solid, which emphasizes the fact that it is necessary to see that the rock is excavated to a sufficient depth to allow a slight settlement of the pipe after it has been laid. It also emphasizes the fact that great care must be taken in maintaining a line to prevent other structures being erected under the main so that there will be sufficient clearance to allow a slight settlement.

The writer has always found public service corporations willing to use due care when the situation was fully explained to them, but has always insisted that all work, where any structure was to pass under the Metropolitan mains, should be inspected while the work was in progress.

The following is a brief description of the most important breaks that have occurred on the Metropolitan Works as listed in the above table. The most costly of the above breaks occurred in Harvard Square, Cambridge, December 24, 1909, about 9.30 P.M., when the supply main between Chestnut Hill and Spot Pond burst, allowing a large quantity of water to escape before the line could be shut off. At the time of the break, work in connection with the new subway to Harvard Square was in progress, and the watchman notified the headquarters of the maintenance force promptly and the gates controlling the flow of water were closed and pressure restored throughout the district in one hour and fifteen minutes. During this interval, however, water was escaping through the orifice in the pipe at a rate, roughly estimated, of 100 000 000 gal. per day, equivalent to 5 200 000 gal., which flooded streets and the basements of several buildings along its course to a lower level. An electric light pole was undermined and the wires fell across the trolley wires, interrupting the car service and making it dangerous to commence immediate repairs. After consulting the chief engineer, he agreed with the writer that it was better to wait until morning before starting the repair work. The line was again ready for use at midnight on December 25. The pipe that broke was a Class C, Metropolitan Water Works' standard, which requires a thickness of metal of 1.4 in. The pipe had been in almost continuous use since January 1, 1899, under a head of 144 ft., until it burst December 24, 1909. The piece blown off by the water pressure was approximately 7 ft. long and 4 ft. wide, with a developed surface of 25.4 sq. ft. The orifice through which the water escaped from the main was about 22.2 sq. ft. The pipe was cracked the entire length of the bottom. The pipe was found to be resting on a concrete duct which had been put in after the pipe was laid, and in order to make a closure it was necessary to remove about three quarters of an inch of this concrete duct before the new pipe could be sleeved in. Many of

INTERIOR VIEW OF BREAK IN 48-IN. METROPOLITAN WATER WORKS SUPPLY MAIN, COMMONWEALTH AVENUE, NEWTON, NOVEMBER 6, 1915.

EXTERIOR VIEW OF BREAK IN 48-IN. METROPOLITAN WATER WORKS SUPPLY MAIN, COMMONWEALTH AVENUE, NEWTON, NOVEMBER 6, 1915.

the basements of the buildings in the immediate vicinity which were flooded contained very valuable goods. The cost of the repair work was $459.07. The cost of the damage to property was approximately $20 000.

Another serious break occurred in the 48-in. main supplying the city of Boston, in Clinton Road, Brookline, at 11.50 P.M., on December 4, 1913. It was necessary to operate five 36-in. valves and one 48-in. valve to shut off the flow of water. In the meantime, for nearly two hours, water was flowing from the orifice at the rate, approximately, of 80 000 000 gal. per day, equivalent to about 6 660 000 gal. The pressure in the city proper was reduced but did not fall below the ordinary pressure furnished during the day. The water flowed down Clinton Road for a distance of about 600 ft. and then across lawns of several private estates, washing lawns and excavating holes along the house foundations to a depth of three to five feet, covering an area of about 1.3 acres. After crossing the private estates, the water continued along Clark Road, removing surface material from the street and sidewalk. Again crossing private property, it undermined a small portion of the Boston & Albany Railroad, finally entering Village Brook, at a distance of about 2 500 ft. from the break. The water entered the basements of five houses, carrying considerable sediment, which was deposited when the water receded. This pipe line was acquired from the city of Boston in September, 1913. The line was laid in 1869 and placed in service in 1871. The greater portion of the line was laid between January 1 and April 1, 1869, and since the line was put in service, thirteen breaks have occurred. Three of these breaks occurred soon after the main was placed in service, and at that time the pressure did not exceed 10 lb. per square inch. On October 10, 1900, the pressure was increased about 10 lb., and during the following two months six breaks occurred, followed by another on June 29, 1901. During the past fifteen years two more breaks have occurred, one on December 14, 1907, and the other, just described, December 4, 1913. The pipes were designed to be about 1.4 in. in thickness and to weigh 8 045 lb. per length. Nearly all the breaks have occurred where the pipe was laid 9 to 14½ ft. below the surface of the ground, which leads to the inference that the weight of the material rather than

the internal water pressure has been the greatest factor in causing these breaks. Measurements were taken of the interior of the pipe, which gave an excess of horizontal over vertical internal diameter at the place where the greatest number of breaks have occurred, of ten-sixteenths of an inch for a maximum and one-sixteenth of an inch for a minimum, an average excess of nine-sixteenths of an inch.

Mr. Frederick I. Winslow, in referring to some of these breaks in an article in the *Engineering News* of July 3, 1902, called them seven mysterious breaks occurring on the Boston Water Works system.

On October 3, 1914, at 10.15 A.M., a 36-in. pipe in one of the two lines into which the 48-in. pipe line is divided where it passes under the Mystic River between Somerville and Medford, was broken by the Eastern Dredging Company's dredge accidentally dropping an 18-in. square, steel-pointed spud on to the pipe. The pipe line under the river is supported on single pile bents under each pipe. A piece of pipe 5 ft. long and 4 ft. wide was broken off. As a result, water flowed from an opening at an average rate of about 75 000 000 gal. per day, while the gates controlling the flow were being closed. The pressure on the northern low-service district was reduced by 25 to 35 lb. below normal for about thirty-five minutes. In removing the broken pipe, it was necessary to blast with dynamite, closure being made with two short lengths sleeved in, the joints being made with lead wool by a diver. The accident occurred in the river channel where there is about twenty-two feet of water at high tide.

On November 6, 1915, a break occurred about 5.30 A.M. on the 48-in. Weston Aqueduct supply main on Commonwealth Avenue, at Auburn Street, Newton. A loss of pressure at the pumping station was noted and the maintenance force notified. The men were assembled, but no report was received of a break on the system. As a break on the Boston mains would show a loss of pressure at the station, inquiry was made of the Boston department, but no report had been received of any break on that system. At 6.40 A.M., no word having been received from local officials, men were sent out to examine our Venturi meter registers and at once found the trouble was on the supply line. A truck, with

men, was at once sent over the line and the break located and the line shut off at 7.45 A.M. The water from this break flooded an area of 7.6 acres, including the basements of six houses, the basement floor of a section of a church, and undermined a part of the track of the Boston & Albany Railroad, also causing more or less damage to the property of fifteen others residing in the vicinity, which required considerable work regrading lawns and shrubbery beds and rebuilding a tennis court. The water escaped from an orifice in the pipe at a rate, roughly estimated, of about 80 000 000 gal. per day, equivalent to a total of 7 500 000 gal. The pipe that broke was Class B, Metropolitan Water Works' standard, which requires a thickness of metal of 1.25 in. The pipe was laid in 1902 and has been in almost continuous service since December 29, 1903, under a head of 145 ft. The pipe was cracked the entire length, and the piece that was blown off by the water pressure was approximately 10 ft. long and 3 ft. wide. The orifice through which the water escaped from the main was about 18 sq. ft. The pipe was covered to a depth of 14 ft. and was crushed by the heavy weight concentrated on the small bearing surface where the pipe rested upon a projecting point of rock which had not been excavated to a sufficient depth when the pipe was laid.

Breaks that occur on local systems are not a disturbing factor to the supply mains of the Metropolitan Works, except those that occur on the larger mains of the Boston system, and during the period covered by this paper there have been thirteen breaks in Boston caused by the pipe being supported at one point on solid foundation, such as subway roofs, timbers, manholes, and sewers.

The total amount paid out for damages on account of the breaks on the Metropolitan Works is approximately $37 000, $20 000 of which was for the Harvard Square break, leaving about $17 000 for the remaining twenty-four breaks, approximately $4 000 of which was paid on account of seven breaks on existing mains taken as part of the Metropolitan Water Works system.

The total cost of stock used on the distribution system of the Metropolitan Water Works, exclusive of the pipe taken from existing works, including pipes, valves, specials, etc., is $2 581 000, which represents the cost of material in the 98.57 miles of mains laid under the direction of the Metropolitan Board.

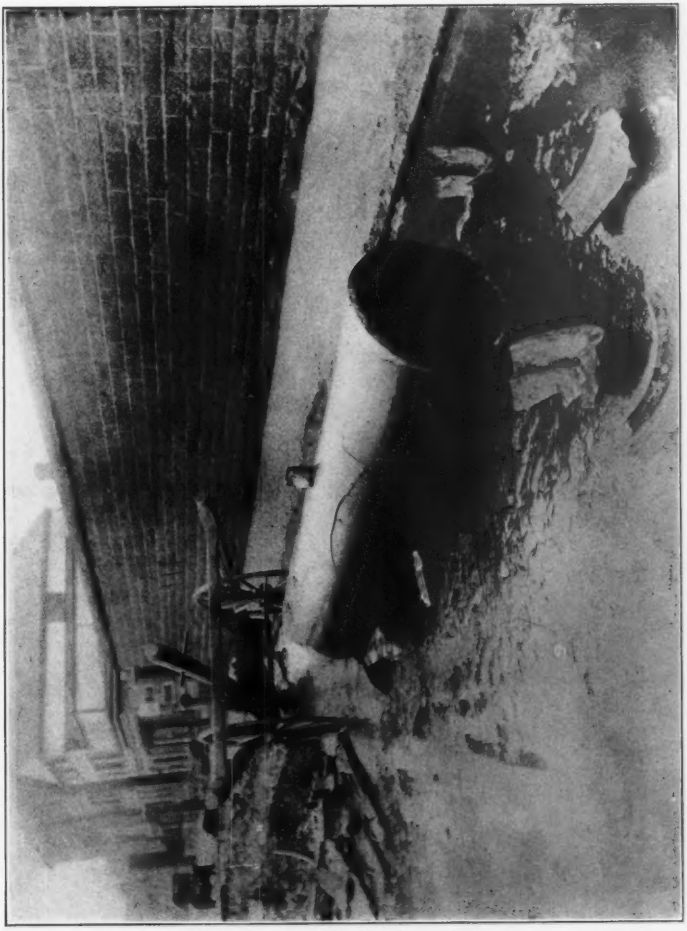
It is the writer's opinion that the time has come when, especially in the larger municipalities, there should be a more thorough study of the conditions of the streets before public service corporations are granted permits for concrete structures. The writer would even go further and require public service corporations laying solid structures under large supply mains upon which a municipality must depend for its supply for fire protection and domestic use to give notice to those in charge of the maintenance of those mains that the work was to be done so that the work could be thoroughly inspected, as, at present, unless the pipe lines are patrolled daily, we find, many times, evidence where work has been done and covered up without our attention being called to it.

The problem of furnishing an unfailing supply of water for various requirements of the larger municipalities, especially in the case of breaks, demands an increasing vigilance on the part of trained men, who must, at all times, be prepared to meet emergencies which are sure to arise. If a serious loss of life and property is to be avoided, intelligent and conscientious work on the part of every employee connected with the water department is a necessity. The efficiency of water-works service is being greatly promoted by the increased use of automobiles for the transportation of men and supplies. The Metropolitan Water Works has recently added to its equipment two emergency service trucks, equipped with gate-operating device, and men will be stationed on duty, at all times, who are capable of operating these when emergencies arise.

## Discussion.

Mr. Saville. We have had several breaks in the last two years, on large size pipes. I have three photographs I would like to put in as evidence in support of Mr. Killam's statement against the rigid support. The first break is on a 24-in. line that encircles the city as a fire line. The pipe is rigidly supported on one side by a sewer manhole. A trench had been dug on one side, and the filling was loose. The pipe dropped under a gas main and was backed with cement on one side. Some settlement occurred and the pipe was cracked the entire length.

Mr. Ackerman. I only wish to cite an instance or two that



BREAK IN 24-IN. PIPE, HARTFORD, CONN.

happened in the city of Auburn, N. Y., and illustrate that it is not always a case of rigid support. In one rocky section of our city during the construction of sewers, there was much blasting. The main sewer had been placed in, and I supposed the danger

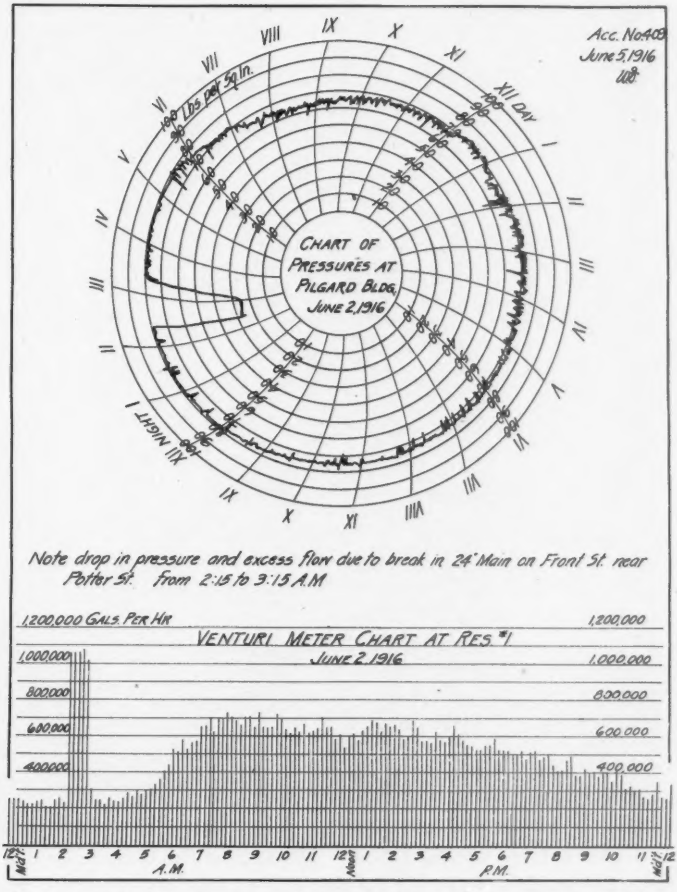



FIG. 1. DROP IN PRESSURE AND INCREASE IN FLOW DUE TO BREAK IN 24-IN. PIPE, HARTFORD, CONN.

was all over, but in placing laterals an Italian had been attempting to connect a trench with a lateral of a sewer and had been using dynamite very freely, and he came to a new kind of rock which

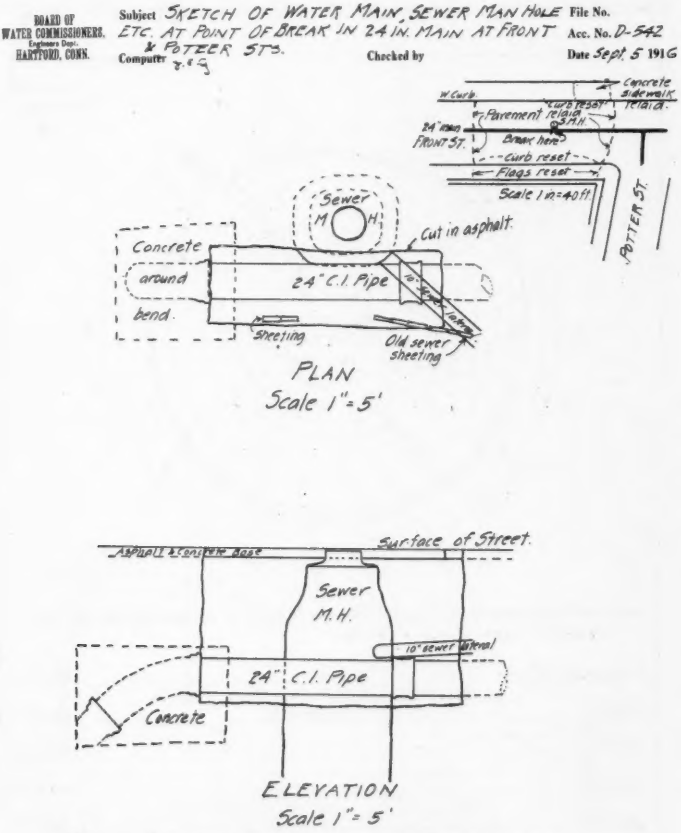
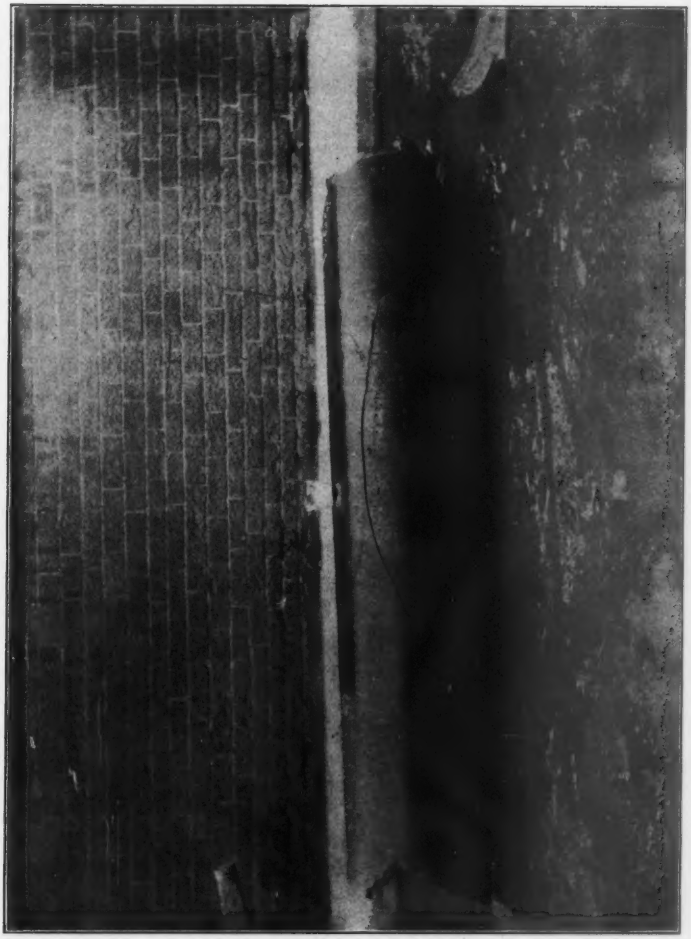



FIG. 2. LOCATION OF 24-IN. PIPE, HARTFORD, CONN.

apparently he couldn't do anything with, so he put a stick of dynamite under it and touched it off. It happened that that peculiar thing he couldn't get out of his way was a 12-in. water main. He got it out of his way, and of course the residents in the vicinity got a lot of water. The last seen of the Italian he was going in a direction as far away from the scene as possible.



BREAK IN 24-IN. PIPE, HARTFORD, CONN.

I might cite one other instance that was very peculiar. An old water course had been made into a sewer, and a fill had been made on that street. A few years later, a line of pipe was placed over this, and that line of pipe had been in service for nearly thirty years. On Hallowe'en, at about two o'clock in the morning, — the usual time, — a party of four people, two ladies and two gentlemen, came to a street intersection, and they saw large quantities of water coming down the street. There was so much they did not want to make the crossing, and they walked up the street a short distance, and the water was coming up at the curb line. There was just a short space between the sidewalk and the curb. They stood there momentarily to see what the trouble was, and while the four of them stood there, sidewalk, people, and all went into a pool that had been made, and two of them came near drowning. We had to pay for suits of clothes, doctors' bills, and fancy dresses.

Mr. Desmond FitzGerald. While it is undoubtedly true that the great majority of breaks in large mains arise from the nature of the supports, there are other causes. One to which I should like to allude, and which is not often referred to, is the danger of breaking a main, at some weak spot, by the too rapid filling of the main, when it has been emptied. Great caution should be used in the first filling of a main and also whenever it has been emptied. If the air has not full opportunity to escape, it will become compressed and react upon the pipe. I have always been very careful in performing this operation, especially towards the latter part of the process, when the main has been nearly filled, and even with ordinary care I have seen the water mount much higher than the source of supply in great surges which sometimes cause considerable anxiety.

Once in my own experience when some other officials attempted to let the water on too suddenly to a 48-in. pipe in the bed of Reservoir No. 1 of the Boston Water Works, the whole pipe for a short distance was blown out of its bed and up into the air, above the surface of the water.

Particular care should also be taken in filling mains from gatehouses. I have seen the roof of a gatehouse nearly blown off by return surges, which are at times even dangerous to those who are doing the work.

# ELECTROLYSIS — TROUBLES CAUSED THEREBY AND REMEDIES WHICH MAY BE APPLIED.

BY ALBERT F. GANZ, PROFESSOR OF ELECTRICAL ENGINEERING, STEVENS INSTITUTE OF TECHNOLOGY, CASTLE POINT, HOBOKEN, N. J.

[*Read March 14, 1917.*]

## INTRODUCTION.

*Electrolysis* is the process of decomposing a chemical compound by means of an electric current. Electrolysis, in the sense in which it will be discussed here and in which you are particularly interested, refers to the corrosion of underground metallic structures, such as iron and lead pipes, by stray electric currents which reach these structures and flow to surrounding soil. Soil, when entirely dry, practically does not conduct electric current. Pure water likewise has such a high electrical resistance, compared with iron or lead, that it may be considered a non-conductor. Water is, however, readily made conducting by the addition of even very small amounts of salts, and conduction through water is therefore always electrolytic. Soil in its natural state is always moist, and on account of dissolved salts, such as chlorides, nitrates, etc., which are always present, is an electrolytic conductor.

Electric current may be conducted by metallic conduction or by electrolytic conduction. Metallic conduction occurs when an electric current passes through a metal, and is characterized by the fact that no chemical change is produced in the conductor, the only effect being the production of heat. Where electric currents, therefore, pass through metallic conductors, such as copper wires, rails, or pipes, they produce no change in these conductors except to raise their temperature. Electrolytic conduction occurs when an electric current passes through an electrolyte, and is characterized by the fact that chemical decomposition occurs at the electrodes where the current enters and leaves the electrolyte.

When an electric current flows from a pipe or other metallic structure to surrounding soil, chemical decomposition of the metal will take place, resulting in corrosion of the pipe or structure. Concrete, when buried in earth, is moist, and it then becomes an electrolytic conductor, so that an electric current flowing from iron to surrounding concrete will corrode the iron by electrolysis.

The mass of a metal corroded by electrolysis in a given time depends only on the "current," and, with the current densities and other conditions usually found in the case of underground pipes, is equal to that calculated by Faraday's law. Iron is oxidized by electrolysis at the rate of approximately 20 lb. per year for every ampere of current flowing from the iron to surrounding soil. Under some conditions, particularly with very small current densities, this corrosion may be considerably greater, while with larger current densities than the above, this corrosion may be considerably less than the theoretical rate. The actual rate may vary in practice from one-half to one and one-half times the theoretical rate. Lead is oxidized by electrolysis under ordinary conditions in soil at a rate equal to approximately 74 lb. for every ampere of current leaving the lead in one year, and this theoretical rate may also vary somewhat in practice. The amount of corrosion produced by electrolysis is independent of the voltage, except in so far as this determines the amount of current flowing, and the smallest fraction of a volt can produce corrosion from electrolysis under suitable conditions.

The rapid corrosion by electrolysis from external currents is usually localized, and results in pitting of the metal. Such pitting may, however, in some cases also result from ordinary soil corrosion, so that the appearance of a corroded metal structure does not by itself afford conclusive evidence as to whether or not the corrosion was produced by electrolysis from external electric current.

Where the direction of current flow between an underground pipe and surrounding soil reverses more or less continually, it has been found that the corrosion occurring during the time that current flows from the pipe is largely offset by a reversed action which occurs during the time that current flows to the pipe. The resultant corrosion by electrolysis from periodically reversed direct

current is for this reason much less than when the current always flows in the same direction, and this corrosion decreases with increasing frequency of reversal. Investigations have shown that even if such reversals occur only once in twenty-four hours the actual amount of corrosion for iron is only about one fourth of what would occur if the same amount of current always flowed from the pipe to surrounding soil.

When an alternating current of commercial frequency flows between a pipe and surrounding soil, the amount of corrosion produced by electrolysis is of the order of one per cent. or less of the corrosion which would be produced by an equal direct current flowing continuously from the pipe to the soil.

### Sources of Stray Currents which may Produce Electrolysis.

Electrical distribution systems which are grounded at two or more points will, by the law of divided circuits, cause currents called "stray currents" to shunt through the earth between the grounded points, and these stray currents frequently reach underground metallic structures and corrode them by electrolysis. In practice, it is found that the most important sources of stray electric currents, which so endanger underground structures, are direct-current electric railways, which use the running tracks in contact with ground for part of the electric circuit.

For such railways, it is the common practice to supply current to the cars from an overhead trolley wire or from a third rail, and to return this current to the power station through the running tracks, supplemented in large systems by return feeders. A single-trolley electric railway is illustrated in Fig. 1. In this figure the path of the electric current from the positive terminal of the generator through the circuit and back to the negative terminal is shown. In such a trolley system the running tracks consist of rail lengths mechanically fastened together by fish plates of steel bridging across the rail ends and bolted to both rails. Such fish plates while mechanically fastening the rail lengths together do not afford good electrical connections between the successive rail lengths. For this reason, copper wires or straps, called rail bonds, are generally used to bridge across the abutting ends of the rail lengths for the purpose of affording a good elec-

trically conducting path between successive rail lengths. The two rails of a single-track road, or the four rails of a double-track road, are also generally connected together at frequent intervals by cross bonds so that the two or the four rails may be available for the return of current. Instead of using copper rail bonds, the rail

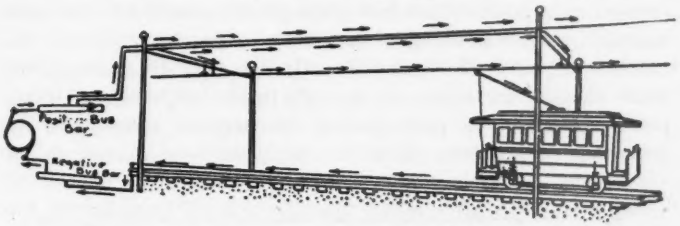


FIG. 1. DIAGRAM OF SINGLE-TROLLEY ELECTRIC RAILWAY SHOWING PATH OF CURRENT FROM GENERATOR THROUGH POSITIVE FEEDERS, TROLLEY WIRE, CAR, AND RAILS.

ends are sometimes welded together, or soft steel plates are welded across each side of the abutting rail ends, thus forming both a strong mechanical and a good electrically conducting connection between the successive rail lengths. To give some idea of the conductivity of steel rails, it may be stated that a single rail weighing 90 lb. per yard has about the same conductivity as a copper wire one inch in diameter. Thus the two rails of a single-track line or the four rails of a double-track line laid with 90-lb. rails and well bonded afford a good conducting path for electric current.

In the simplest form of single-trolley railway, shown in Fig. 1, the rails are connected to the negative terminal of the generator at the power station, and the only path for current to return to the power station is by way of the running tracks. If the running tracks are laid upon wooden ties above ground with broken stone for road ballast, as is common on steam railroads which run on their own right-of-way, the rails do not come in direct contact with ground, and the return current will be practically confined to the running tracks. If, however, the running tracks are laid below ground so that the top of the rails is level with the surface of the street, as is common in cities, then the rails will be exposed for a considerable area to contact with ground. If the tracks are laid on a concrete base, a considerable area of the rails will simi-

larly be in contact with the concrete. Since both damp soil and damp concrete are, under ordinary conditions, conductors of electricity, part of the current returning through the rails will shunt from the rails through the neighboring earth, as is illustrated diagrammatically in Fig. 2. It will be seen that with the usual connection of positive terminal of the generator to the trolley wire, and the negative terminal to the rails near the power station, the current will leave the rails for earth at points distant from the power station, and return to the rails in the neighborhood of the power station, in its path back to the negative terminal of the generator. Since every electric circuit must be completely closed,

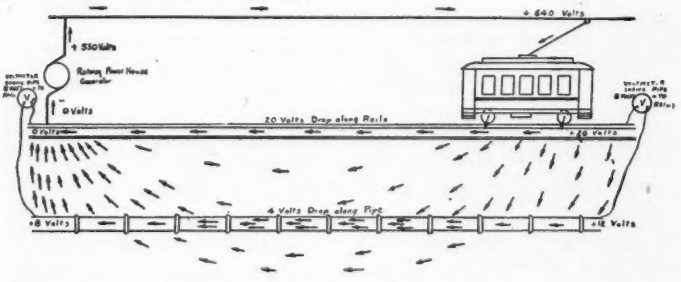



FIG. 2. DIAGRAM SHOWING STRAY RAILWAY CURRENTS WITH ASSUMED DISTRIBUTION OF POTENTIALS CAUSED BY THESE CURRENTS.

all current escaping through earth must again leave earth to return to the dynamo so as to complete the electric circuit. Where underground metallic structures, such as gas or water pipes, lie in earth in the path of these stray currents, and where these pipes have electrically conducting joints, — such as lead-calked joints or screw-coupling joints, — current will flow from earth to such pipes and flow on such pipes towards the power station. In the neighborhood of the power station this current will leave the pipes to return through earth and the tracks to the negative terminal of the generator, as shown in Fig. 2.

If the negative terminal of the generator or negative bus-bar is connected to the rails at points some distance from the power station by means of insulated negative return feeders, then at

such connection-points the rails will be rendered negative in potential to earth, and currents will tend to flow from underground pipes through earth to return to the rails in the neighborhood of these connections. Such stray railway currents on pipes will therefore tend to leave these pipes to return to the rails in all regions where these rails are connected to return feeders.

It has been suggested to reverse the usual arrangement of trolley system and make the rails the positive conductor instead of the negative conductor. With the rails the positive conductor stray current flows to underground pipes in the vicinity of the power station, and leaves these pipes over widely scattered areas so that the density of the current leaving will be relatively small. By this arrangement the acute danger which with the usual polarity exists in the neighborhood of each station is removed, but electrolysis troubles are spread over a greatly distributed area. The total amount of electrolysis must, however, be the same whether the rails are the negative or the positive conductor, since the stray currents through earth are simply reversed in direction but not changed in magnitude. This arrangement has been tried in several places and has been used in one large city for about three years. I have had occasion to make tests in this city and have found that trouble from electrolysis is developing in outlying sections, and some trouble from corrosion of service pipes in such outlying sections has already been found.

It must be noted that, while ordinary soil is a conductor of electricity, its electrical resistivity compared with metals is enormously high, being of the order of millions of times the resistivity of iron. Resistance, however, varies inversely as the cross-section of a conductor, and with the large surface of rails exposed to the earth, the cross-section of the path of current through earth is enormously great compared with the cross-section of the path of current through the rails. As a matter of practice, it is often found that where the rails in contact with earth are used alone for the return of current, a considerable portion of the total current leaks from rails through earth.

The leakage of current from the rails of electric railways, producing stray currents through earth and on underground piping, does not constitute a source of loss to the railway company, as, for

instance, would be the case with leakage of gas or water. On the contrary, by allowing the current to return by earth and underground pipes as well as by way of the rails, the total conductivity of the return circuit is increased, and the voltage loss in the return of this current is decreased, so that there is an actual saving of power for the railway company.

Alternating currents have been used for some years past in a number of electric railways employing the running tracks as a part of the electric circuit, and where these tracks are in contact with earth, stray alternating currents through earth are produced. Where an alternating current flows from iron or lead to surrounding soil, corrosion from electrolysis may also be produced, but this proceeds at a relatively very slow rate, as already explained. With alternating currents, electrolysis is, however, produced at the two electrodes, instead of at one electrode only, as with direct current. So far as the writer is aware, no damage from electrolysis due to such stray alternating railway currents has been reported to this date. This may be due to the slow rate at which corrosion is produced by alternating currents, together with the fact that most of these railways are of relatively recent installation. It may also be due to the fact that stray direct currents are nearly always present with the alternating currents, and the effects of these direct currents may have inhibited or masked the effect of the alternating currents. It is therefore not possible at this time to draw a positive conclusion as to the danger from stray alternating currents.

### General Effects of Stray Electric Currents on Underground Piping.

The current flowing through the rails from the trolley cars back to the power station produces in these rails a drop in potential; that is to say, points in the rail away from the power station have a positive potential with reference to the rails at the power station. Since potentials are measured relatively, it is convenient to consider the negative terminal of the dynamo, which is assumed connected to the rails at the power station, as at zero potential. The distribution of potentials in the rails of a simple electric railway system and in the underground piping is illustrated in Fig. 2, in

which convenient values have been assumed. It will be noted that the underground pipes are negative to the rails at points away from the power station, and positive to the rails near the power station. It is also seen that the negative potential of the pipe, plus the drop on the pipe, plus the positive potential of the pipe, equals the drop in the rails. In the case assumed, there is a potential difference of 550 volts maintained at the power station; of this, 10 volts is lost in the trolley wire, 520 volts is used by the motors of the car, and 20 volts is left to bring the current back to the power station. If the negative bus-bar and the rails at the power station are considered as at zero potential, the rails at the car in the assumed case will have a potential of 20 volts. Thus, for practical purposes, the earth with its underground pipes is subjected to a potential difference of 20 volts, and the amount of stray current produced is that due to these 20 volts. If the rails are laid in the usual way, that is, in contact with ground, the 20 volts in the rails will send some shunting current through the earth and on the underground pipe as shown in the diagram. Under the assumed conditions, there is a drop of 8 volts from the rails to the pipe near the car, a drop of 4 volts in the pipe itself, and a drop of 8 volts from the pipe through earth to the rails at the power station. It is therefore seen that it is the voltage drop in grounded rails caused by the return current which is the cause of stray currents through earth.

From the explanation of metallic and electrolytic conduction given in the first part of the paper, it will be understood that where stray currents flow on underground pipes they do no harm except where they leave the pipes to flow to the surrounding soil. At such points corrosion of the iron from electrolysis will take place. In the simplest case, illustrated in Fig. 2, current flows from rails through earth to the pipes at points distant from the power station, flows on the pipes, and leaves the pipes to return through earth to the rails in the neighborhood of the power station. Where the current flows from the rails to earth, the rails will be corroded, and where the current flows from the pipes to earth, the pipes will be corroded. If the pipe line is a uniform electrical conductor, and the relative arrangements are as shown in Fig. 2, then the pipes will be corroded only in the neighborhood of the power sta-

tion. If, however, the pipe line is not a uniform conductor, — as, for instance, if there are one or more high resistance joints in this pipe line, — then the current on the pipe will shunt around such high-resistance joints and produce oxidation or corrosion on the positive sides of the joints. Where there are two or more underground piping systems, it also frequently happens that current shunts from one system to another through the intervening soil, producing electrolytic corrosion where the current leaves the pipes. Such shunting currents are often caused by accidental high-resistance joints in one of the pipe lines, and such shunting may occur anywhere and without reference to the location of the railway power station. Where a direct-current trolley system passes through a town which has an independent piping network, and where the power station supplying the trolley line is in some other locality, then if stray electric currents are produced by the trolley line where it passes through the town, they will flow on the piping system, making this piping system positive to earth and to rails at points nearest the railway power station, and negative at points farthest away from the power station. In this case electrolysis of the piping will be produced at the ends of the piping system which are nearest to the power station.

Where current leaves a wrought-iron or steel pipe for earth, the oxide of iron resulting from electrolysis becomes diffused through the earth, and streaks of iron oxide can generally be found in the surrounding soil. Electrolysis of wrought-iron or steel pipes usually results in pits which eventually go entirely through the wall of the pipe. It has frequently been found, in practice, that where a gas service pipe lies in clay or other tightly packed soil, it may be pitted through in many places without giving any external sign of leakage, because the soil surrounding the pipe maintains it gas-tight. When cast iron is corroded by electrolysis, the oxides of iron mixed with graphite usually remain in place, leaving the outside appearance of the pipe unchanged. This material, resulting from the electrolysis of cast iron, usually has the consistency of hard graphite, and can be cut with a pocket knife. There have been many cases in which a cast-iron main was carrying gas or water without any apparent leak, where a light blow with a hammer drove a hole right through the pipe. Here

the electrolytic action had corroded the iron entirely through the pipe, and the oxide of iron had remained in place, and, together with the surrounding soil, had prevented the pipe from leaking. Whether or not the mixture of iron oxide and graphite resulting from electrolysis remains in place so as to maintain a pipe gas- or water-tight, depends upon the surrounding soil conditions. It is therefore seen that an underground piping system may be suffering severely from electrolysis without giving any outward sign of the damage. A physical examination with a test hammer is required in the case of cast-iron pipe to establish definitely whether or not it has been damaged by electrolysis.

For a given current leaving a pipe, there is practically no difference between cast iron, wrought iron, and steel, in the amount of iron destroyed. The electrical resistivity of cast iron is, however, about ten times as great as that of wrought iron or steel, and the usual lead joints in cast-iron pipes also have a resistance which is many times greater than the screw-coupling joints used with wrought-iron and steel pipes. A given voltage drop through earth will therefore cause a much smaller current to flow on a cast-iron pipe than on a wrought-iron or steel pipe, thus making cast-iron pipes much less subject to electrolysis than wrought-iron or steel pipes.

### Electrolysis Surveys on Underground Piping Systems.

In order to determine the electrolysis conditions of an underground water-piping system, a potential survey and a current survey are generally made. Where it is also desired to determine what remedial measures should be applied for protection against electrolysis, tests of the current and voltage distribution in the grounded circuits of the electric railway system by which the stray currents are produced should also be made.

In the potential survey, voltage measurements between the water pipes and trolley rails and between the water pipes and all other neighboring underground piping and cable systems are made at a number of selected locations. They should preferably be made simultaneously between all of the structures tested at any given location, and either indicating or recording voltmeters may be employed; but the tests should be made for a sufficiently long

period at each location to cover a complete cycle of car operation. Where the water pipe itself is not exposed, connections for these voltmeter measurements may be obtained by means of house service pipes, which are satisfactory for these tests, because the voltmeter has a high resistance and takes only a very small current.

The current survey consists of measurements of current flow on pipes at selected locations in the piping system. To determine the current flowing on a pipe, the voltage drop between two points on a continuous length of pipe is measured by means of a millivoltmeter. From this voltage drop and from the resistance of the included pipe, which may be obtained from published tables, the strength of the current is computed. To measure this drop it

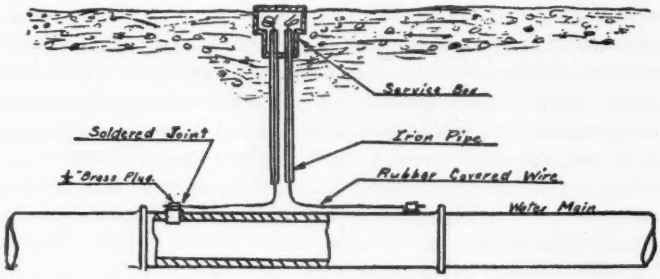



FIG. 3. PERMANENT ELECTRICAL TEST WIRES ATTACHED TO MAIN AND BROUGHT TO SURFACE OF STREET THROUGH SERVICE BOX.

is necessary to expose the pipe and to make good electrical contact between the millivoltmeter leads and the pipe. The best contact for these current measurements is obtained by soldering the connecting wires directly to the pipe or to two brass plugs screwed into the pipe. This method is particularly advantageous when readings are to be taken over a considerable time, and it is customary to use rubber-covered wires and bring them to the surface of the street, leaving the ends in service boxes, which then form permanent stations for electrical measurements. This is exceedingly convenient because it is then possible to make current measurements on the pipe without again making an excavation. Such permanent contact wires are illustrated in Fig. 3.

It should be noted that small potential differences, such as 0.1 millivolt or less, may be caused by local galvanic or thermal action. Where such small values are found in a test for drop on a pipe, a careful investigation should be made to ascertain whether the observed potential difference is actually drop due to current flow. The writer has found that such small potential differences are a frequent source of error when tests are made by persons who are not experienced in making such electrical measurements.

Since current destroys metal only where it leaves for soil, it is important to know where the current leaves a pipe. Current measurements on pipes are therefore frequently made at two or more stations simultaneously in order to determine the change in current on the pipe between the stations. For these current measurements, indicating or recording millivoltmeters are employed. By comparing the characteristic variations of currents and voltages measured for twenty-four-hour periods at selected locations with the characteristics of the neighboring electric railways, it is often possible to identify the source of the stray current flowing on a pipe.

From a study of the results of the potential and current surveys it can be determined where current is leaving the piping, and at a number of such points excavations should then be made and the exposed pipe examined with a test hammer for corrosion of the iron. Where corrosion and pitting is found at points where current is leaving the pipe, it may be taken as evidence that at least part if not all of the corrosion has been caused by electrolysis, because it has been conclusively proven that whenever current flows from iron to surrounding natural soil, corresponding corrosion of the iron by electrolysis takes place.

From a complete and properly analyzed electrolysis survey, a great deal of good can generally be accomplished. It will not always be possible to remove all stray currents from the pipes, but measures will be indicated by which the conditions can be greatly improved, and points of greatest danger will be located.

## Remedial Measures Applied to Pipes.

Attempts have been made to protect underground pipes from electrolysis by insulating them from earth by paints or dips.

Practical experience as well as a large number of tests have, however, shown that no dip or paint will permanently protect a pipe against electrolysis in wet soil. The first difficulty is to apply the paint so as to form an absolutely perfect coating, and the second one is to prevent mechanical damage to the coating during shipment and installation of the pipe. In the case of paints which are applied with a brush, these afford only a very thin coating over the metal, and where stray currents are present, the effect of these currents and of the moist soil is to cause the coating to disintegrate and disappear rapidly. A large number of experiments which I have made have shown that such paints will disintegrate not only where the current flow is from the metal to earth, but also where the flow is from earth to the metal. Experience further shows that even where coatings of paints or dips are apparently intact, electrolytic action is not always prevented, and, in fact, very serious electrolytic pittings have been found under apparently good coatings. It has been found that in most cases the applied coatings have either been completely destroyed by the effects of the wet soil and the electric currents, or defects in the coating have developed, causing concentrated corrosion at such defective spots. Where it is attempted to apply a heated material like pitch or asphaltum to a cold pipe, it is impossible to completely cover the pipe. Pitch and similar compounds have been applied to pipes with wrappings of jute or of some similar material. A number of layers can be applied in this way so as to build up any desired thickness of insulating covering. Such covering if sufficiently thick will afford protection against electrolysis, provided that it is mechanically perfect. The great difficulty in practice is to apply such a covering without leaving defective spots through which moisture will have access to the metal of the pipe.

Pipes which are covered with imperfect insulating coatings, or coverings exposing bare spots of metal, are in much greater danger from electrolysis where positive to earth than are bare pipes, for the reason that the stray currents will leave only from these bare spots, and here produce concentrated corrosion. The writer has seen cases where a pipe coated with an imperfect insulating covering was pitted nearly through in one year, whereas

a bare pipe in the same locality was very much less affected, because the corrosion was distributed over a larger surface.

One form of insulating covering which appears to afford complete protection is a layer of from one to two inches of a material like coal-tar pitch, parolite, or asphaltum, of such a grade that it is not brittle, and so will not crack, but yet is hard enough to remain in place. The best way to apply such a layer is to surround the pipe with a wooden box, support the pipe upon creosoted blocks of wood or upon blocks of glass, and then fill the space between the box and the pipe with the molten material. When applying this material, great care must be exercised to avoid getting stones or dirt into the mixture, and also to avoid leaving bare spots on the pipe. The cost of carrying out such an installation is prohibitive, however, except in very special cases, such as that of service pipes in very bad localities, or that of very important individual pipe lines of small or medium size. Embedding a pipe in cement or concrete, even if this is several inches in thickness, will not protect it from electrolysis, because damp cement or concrete is an electrolytic conductor.

Insulating covering, even if imperfect, is useful on pipes in negative districts where current flows from earth to the pipes, because this covering will increase the resistance from earth to the pipes and thereby correspondingly reduce the amount of current reaching the pipes.

Current flow on metallic pipe lines can be practically prevented by using a sufficient number of insulating joints. A pipe line laid with every joint an insulating joint has a comparatively high resistance, and no substantial current can flow on such a line. It is sometimes possible in the case of individual pipe lines to use comparatively few insulating joints to break up the electrical continuity of the line and substantially protect it from electrolysis, but such joints must be installed only after adequate tests have shown that sufficient current will not leave the pipe on the positive side of any joint to flow to earth and do serious damage by electrolysis. Insulating joints in pipe lines should not be confined to the positive areas, but should be installed in all places along the pipe line where there is any considerable potential gradient in the earth parallel to the pipe. The frequency with which insulating

joints must be installed in a pipe line in order to assure reasonable protection from electrolysis depends upon the potential gradient through earth and upon the electrical resistivity of the earth. The effective resistance of a short insulating joint is practically the same as that of a long joint, but a long insulating joint gives a more even distribution of leakage current than a short joint. Hence a long insulating joint is to be preferred where there is considerable potential difference across the joint, or where the resistance of the surrounding earth is low. The effect of a long joint can be practically secured from a short insulating joint by surrounding the joint and the pipe for from 5 to 25 ft. on each side of the joint with a heavy layer of insulating material.

Where service pipes are endangered by current which flows to them either from the main or from house piping, such current flow can be prevented and the service pipes protected by placing insulating joints in them at the main or in the building, or at both locations.

Insulating covering and insulating joints can be applied in special cases to individual pipes, but cannot ordinarily be applied in an extensive manner to a piping network.

A method of mitigating electrolysis which has frequently been employed in this country is pipe drainage. This consists of connecting the pipes to the railway return circuit at a sufficient number of points to render the pipes at all points negative to the electric railway tracks. Electrical drainage was first applied to lead cable sheaths, and the success in protecting cable sheaths in this manner led to the attempts to apply the drainage method also to pipes. There are marked differences, however, between an underground piping system and a lead cable system, which render the piping system much less suited to electrical drainage. The principal difference is that cable sheaths are continuous electrical conductors, while pipes may be more or less discontinuous, owing to the presence of high resistance joints. Another difference is that the lead cable sheaths are relatively small and are carried in ducts, which are mostly non-metallic, so that only a part of the surface of the cables is grounded, whereas underground pipes are buried directly in earth and generally present enormous contact areas to earth. The result is that, when electrical drainage is

applied to pipes, the currents on the pipes are very greatly increased. This increases the danger of current shunting around high resistance joints or leaving the pipe on the positive side of a joint to flow to other structures.

Draining the piping system to the negative bus-bar, when applied as the principal means for mitigating electrolysis, always largely increases the total current flowing on the piping system. When two piping systems, such as a gas and a water piping system, are drained to the negative bus-bar, large currents are caused to flow not only on the water and gas mains, but are frequently also caused to circulate between the gas and water mains through house service connections, because of varying resistances in the pipe joints. Such circulating currents are a serious fire hazard to the buildings through which they pass. Large currents on mains are also dangerous in cases where repairs are being made, because when a pipe carrying a large current is disconnected, an electric arc is produced at the point of separation. I have heard of numerous cases where such arcing set gas or oil on fire, and caused not only damage to property but serious injury to workmen. In many cases where pipe drainage is used, such large currents flow on the pipes that it is not safe to disconnect a pipe without first connecting a copper wire jumper across the proposed break.

Generally the only electrical measurements which are made before and after a system of pipe drainage has been installed are measurements of the potential difference between pipes and the rails. These measurements are ordinarily plotted on a map of the railway system, the values of the potential differences being laid off as normals to the railway lines, and these normals are connected by straight lines. The areas indicating pipes positive to rails are then colored red, and the areas indicating pipes negative to rails are colored blue. Before the pipe drainage is installed there are generally large red areas, indicating pipes positive to rails, while after the drainage has been installed there are only blue areas. The conclusion is then drawn that since the map giving the measurements after the drainage has been installed shows no red areas, all electrolysis troubles have been eliminated and the piping system is now safe against destruction by electrolysis. This would be true if the piping were a continuous and uniform

electrical conductor, and if there were no other underground metallic structures in the earth in the same locality. In any considerable network of underground pipes, there are always joints of widely varying resistances and generally many joints of high resistance, so that current instead of flowing continuously along the pipes may jump around high resistance joints or from one part of the network to another part. The blue areas on the map showing the potentials of the pipes referred to rails of course do not show this. Further, since there are always other underground structures, such as pipes or cables, present in the earth, current may flow between the various structures. The blue colored map also fails to show this. In my opinion, a pair of maps, as described above, shown for the purpose of proving that electrolysis has been eliminated on any underground system, are, to say the least, misleading. The complete data from which to judge the effectiveness of a drainage system would involve the results of many other tests, particularly of currents on pipes, of drop across joints in the pipes, and of potential differences between the drained pipes and all other neighboring underground structures. These additional measurements should be made at a large number of well-distributed locations. Owing to the inaccessibility of the pipes, it is generally impossible to make such tests, so that complete data on a system which is drained cannot be practically obtained.

Once electrical drainage is applied, it is usually found that thereafter everything is left to take care of itself, and no attention is paid to the railway return circuit. The writer experienced a most striking example of this in a city in the northern part of New York State a few years ago. It was reported that persons received electric shocks by touching water and gas pipes. Investigation showed that in the neighborhood of the railway substation, where the worst trouble had been experienced, the gas pipes were from 50 to 100 volts positive in potential to the water pipes. Tests made on the tracks in the neighborhood of this station showed practically no current flowing in the rails. Further investigation showed that the water pipes were connected to the negative bus-bar in the station by a large copper cable, and that this cable was draining the entire station load from the water pipes to the negative bus-bar. Still further investigation showed that the con-

nection from the negative return cables to the tracks, directly in front of the substation, had been corroded off so that there was no metallic connection whatever from the tracks to the negative bus-bar, and all of the current was forced to return by way of the earth and underground structures, and finally by the water pipe drainage cable to the negative bus-bar. This condition of affairs had existed for a number of weeks and had not been discovered by the railway company.

When electrical drainage is applied to a single system of underground pipes, without making a complete investigation of the effects of possible high resistance joints, etc., the installation may be made at relatively small cost, and, when so applied, it usually relieves the acute danger from electrolysis in the immediate neighborhood where the drainage connections are made. Both of these considerations have served to favor the electrical drainage system. However, a single drained underground piping system becomes a source of serious danger to other systems. If electrical drainage is applied comprehensively to all underground metallic systems, it will not only be found very expensive to install but, likewise, expensive to maintain, because as railway and piping systems are changed, the drainage system must also be changed accordingly. The large increase in current on underground structures produced by electrically draining them also brings about dangerous conditions at scattered and unknown places, which is a serious objection to this method. A further and perhaps the most serious objection to the drainage system is that sufficiently complete tests cannot be practically made to determine whether the drained system is safe or is still in danger from electrolysis.

In future installations of underground piping systems in the neighborhood of electric railways, precautions should be taken to minimize the flow of stray current to the pipes. To this end, the pipes should be laid as far from the electric railway tracks as practicable. Metallic contacts with the tracks, such as may exist at the iron gate boxes used in water piping systems, must be carefully avoided. Where the pipes cross steel bridges carrying electric railway tracks in metallic contact with the bridge structure, the pipes should be supported on wooden blocks or otherwise insulated from the metal of the bridge structure. Insulating

joints should be installed at the entrance of pipes to car barns, as it is frequently found that the pipes inside of the barns are in metallic contact with the tracks through the building structure. In special cases of individual pipe lines, insulating joints and, in some cases, also insulating covering of adequate thickness, may be employed in localized sections where conditions are found to be suited to their installation.

### Remedial Measures Applied to Electric Railways.

The only way to entirely prevent electrolysis from stray railway currents is to prevent leakage of currents to earth from electric railway systems by the use of a separate and completely insulated return conductor, instead of using the running tracks as part of the return circuit. This is accomplished with the double underground trolley system, in use on the surface lines on Manhattan Island and in the central district of Washington, D. C., and with the double overhead trolley system, in use on the surface lines in Cincinnati, Ohio, and on some of the outlying surface lines in Washington, D. C., and in Seattle, Wash. These systems, while entirely effective in preventing electrolysis, have, however, not been generally adopted, probably because of the added expense and of the added complication involved over the ordinary single-trolley system, which latter has come into practically universal use.

To change a single trolley to a double-trolley system would involve a more or less complete change in system. While leakage of current from single-trolley electric railways cannot be entirely prevented by any methods that can be applied to these railways, the amount of stray current produced by a single-trolley railway can by adequate measures be reduced to any desired minimum values. As already shown, the direct cause of stray currents from electric railways is voltage drop in the running tracks. It is, therefore, clear that, by reducing this voltage drop, the stray currents leaking from such tracks will be correspondingly reduced. Since stray currents must flow from the tracks to earth, the amount of stray current produced by a given voltage drop is also dependent upon the resistance between the tracks and earth. The

leakage of currents from the tracks can, therefore, be likewise reduced by increasing the resistance between the tracks and earth. The reduction of stray currents through earth can best be accomplished by the following means, given in the order of their importance:

(1) By increasing the number of direct-current supply stations in systems extending over large areas, so as to reduce the radius to which any one station supplies current, and also by supplying all of the railways in any locality from one supply station in this locality. The increase in the number of supply stations has been brought about in several American cities through the unification of electric light and electric railway interests, whereby the joint utilization of electric light and railway substations for the supply of the railways has been made possible.

(2) By increasing the electrical conductance of the tracks, through the use of heavy rails, through the use of low-resistance rail joint bonds and cross bonds, and through the interconnection of the electric railway tracks of all systems, where these come close together.

(3) By removing current from the tracks by insulated return feeders, and by maintaining the negative bus-bar insulated from ground at the supply station, in all cases where the voltage drop in the tracks would otherwise be excessive. This arrangement is known as the *insulated track feeder system*, or the *insulated return feeder system*.

(4) By increasing the resistance between tracks and earth as much as practicable, through draining the roadbed and, on private right-of-way, through maintaining the rails out of contact with earth.

Where a road operates on a private right-of-way, the rails can often be practically insulated from ground and the escape of current from the tracks prevented. For surface roads this can be accomplished by placing the rails on wooden ties above ground and using broken stone for ballast and keeping the rails out of contact with ground. In the case of railway lines operating on elevated structures, the rails can be fastened to wooden ties and kept out of contact with the structures. These rails, supplemented where necessary with negative feeder cables, also insulated from

the structure, can then be used for the return conductor. In this way the return circuit is quite thoroughly insulated from the elevated structure and from earth, and stray currents are entirely prevented.

It has been proposed to employ a 3-wire system for distributing current to an electric railway. In this system pairs of generators in the power station are connected in series, and the junction point between the two generators is connected to a neutral bus-bar. The trolley line is divided into sections, and half of the sections are connected to the positive side of the generators and the other half to the negative side. The tracks become the neutral conductor and are connected to the neutral bus-bar at the power station. With this arrangement current flows in the tracks between the positive and negative line sections. The current flowing in the connection between tracks and the neutral bus-bar at the station is the difference between the current used on the positive and negative lines, and is therefore a relatively small current. This current also reverses more or less continually in direction, owing to the continually shifting loads, so that the polarity of the tracks with reference to underground structures at the power station also reverses more or less continually. With this arrangement the concentrated positive zone, usually present in the neighborhood of the power station, is removed, and there is in the neighborhood of the power station a low reversing potential condition. Current flowing in the tracks between the positive and negative sections is also relatively small compared with the current returned by the tracks with the usual arrangement of 2-wire system, so that the practical effect of the 3-wire system is to very greatly reduce the track voltage drop and correspondingly reduce the total amount of corrosion from electrolysis. In addition to this, the remaining corrosion from electrolysis is distributed over widely scattered areas. The 3-wire system has been in use to some extent in Europe, and experimental 3-wire installations are now in operation in two American cities.

The insulated track feeder system, in conjunction with proper track bonding, usually affords the most feasible means for reducing track voltage drop and thereby reducing stray currents through earth in an existing electric railway. In this system, feeders in-

sulated from earth are connected from the negative bus-bar to selected points on the track network.

Diagrammatic sketches illustrating the negative connections of an electric railway with and without the insulated return feeder system are shown in Fig. 4. In this figure the railway lines are assumed radiating out from the power station. In the left-hand diagram the rails of these lines are shown connected to the negative bus-bar at the power station only. It is seen that, as the result of this, all of the current used on the eight railway lines flows toward the power station in the rails. The stray currents which leak from the rails to earth also concentrate in earth and on the underground piping in the neighborhood of the railway power

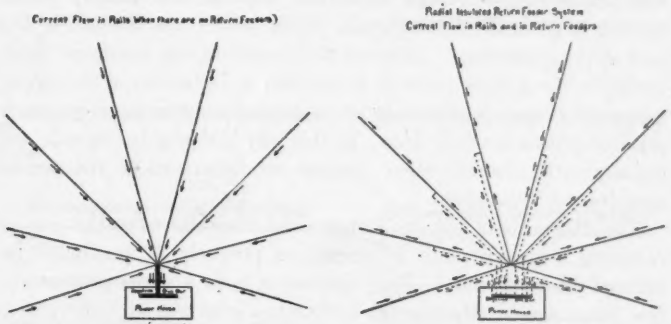

Current Flow in Rails When there are no Return Feeders)
Power House
Radial Insulated Return Feeder System
Current Flow in Rails and in Return Feeders
Power House

FIG. 4. DIAGRAMS SHOWING TROLLEY LINES RADIATING OUT FROM POWER STATION WITH AND WITHOUT INSULATED RETURN FEEDERS, AND SHOWING PATH OF RETURN CURRENTS.

station, where they must return to the rails to get back to the negative bus-bar.

If this connection between the negative bus-bar and the rails at the power station is removed, and the currents collected from the rails at points near the center of each railway line by means of insulated track feeders, as shown in the right-hand diagram of Fig. 4, the concentration of current in the neighborhood of the power station is entirely removed. With this arrangement the current used by each individual line tends to flow away from the rails at both ends of this line, and toward the rails near the center

of the line. It is therefore seen that only one eighth of the current is collected from the rails at any one point that there is when the rails are connected to the negative bus-bar only at the power station. Further, assuming similar soil conditions, the total stray current through earth with the conditions shown in the right-hand diagram will be only one fourth of the total stray current with the conditions of the left-hand diagram, so that at any one point, the danger from electrolysis will be one thirty-second of what it is in the neighborhood of the power station with the first arrangement. As a matter of practice, however, the actual reduction is very much greater, because the track feeder connection-points to the rails can be chosen so as to be located where the ground is high and dry, and consequently of high resistance, whereas the railway power station is generally located near water, where the ground is wet and of low resistance. Instead of connecting one insulated track feeder to the middle point of every line, as indicated in the figure, a number of such feeders may be connected to a number of properly selected points in every line. In this way the drop in the rails and consequently also the stray current produced can be reduced to any desired low value.

The diagrams of Fig. 5 illustrate the possibilities in the way of reducing stray currents by means of properly proportioned insulated return feeders. They are taken from a paper presented a few years ago by Mr. George I. Rhodes, who was at that time in the employ of the Interborough Rapid Transit Company of New York City. This company installed a system of insulated track feeders in connection with its subway systems in New York City. The diagrams in Fig. 5 illustrate the relative amounts of leakage current with various connections from the tracks to the negative bus-bar of the power station. It will be seen that with the negative bus-bar grounded through a connection of negligible resistance, in addition to being connected to the rails at the power station, the greatest amount of stray current is produced, which is assumed unity for the purpose of comparison. This is illustrated by Diagram A of Fig. 5. Disconnecting the negative bus-bar from earth at the station, but not from rails, reduces stray currents to one fifth of their former value, as illustrated by Diagram B of Fig. 5. Disconnecting the negative bus-bar from earth

and from the rails at the power station, and returning the current by means of one insulated track feeder from the center of the line, reduces stray currents to 5 per cent. of their former value, as illustrated by Diagram C of Fig. 5. By using two insulated track feeders, with the negative bus-bar insulated, the stray currents are reduced to 1.2 per cent. of their former value, as illustrated by Diagram D of Fig. 5. It will therefore be seen that very great reduction of stray currents can be accomplished by insulating the negative bus-bar at the power station from earth and from rails, and returning the current by means of insulated track feeders.

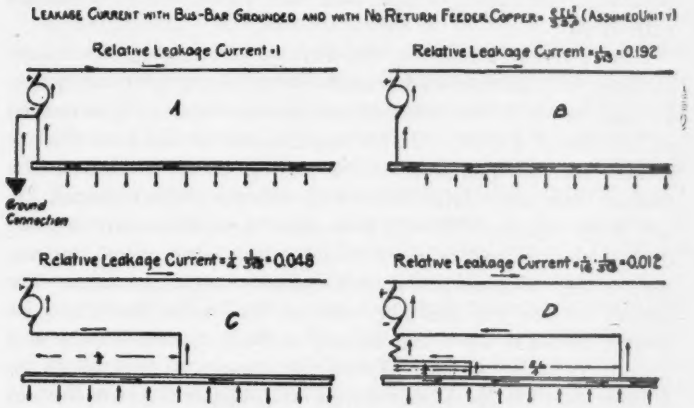

Leakage Current with Bus-Bar Grounded and with No Return Feeder Copper = $\frac{5 \cdot 1^2}{5 \cdot 5^2}$ (Assumed Unit y)
Relative Leakage Current = 1
A
Ground Connection
Relative Leakage Current = $\frac{1}{5^3}$ = 0.192
B
Relative Leakage Current = $\frac{1}{2} \cdot \frac{1}{5^3}$ = 0.048
C
Relative Leakage Current = $\frac{1}{10} \cdot \frac{1}{5^3}$ = 0.012
D

FIG. 5. RELATIVE LEAKAGE CURRENTS WITH VARIOUS RETURN-CIRCUIT CONDITIONS.

The insulated track feeder system is frequently confused with the system of *paralleling the tracks* with return feeders, which has been most commonly used in American electric railways. From the standpoint of reducing track voltage drop, the two systems are, however, totally different. With copper feeders paralleling the tracks, the voltage drop in the tracks is reduced only in the proportion that the conductance of the track circuit is increased. For example, an amount of paralleling copper equal in conductance to the tracks could at best only reduce the drop in these tracks to one half. It is therefore evident that, where the voltage drop in

tracks is high, this system would require a prohibitive amount of copper to reduce the voltage drop to reasonably low values. With the insulated track feeder system, on the other hand, the voltage drop in the insulated feeders does not occur in the tracks nor in the earth, and therefore may be made as high as economy dictates. It should be emphasized that with insulated feeders, the tracks in the immediate neighborhood of the power supply station should be connected to the negative bus-bar only through a suitable resistance, since a direct connection at this point would practically convert the insulated feeder system into a system of feeders paralleling the tracks, because both ends would then be in contact with earth.

I have recently had the opportunity of studying the results obtained with an insulated track feeder system in a city of moderate size, in which the direct-current railway substation is located on one side of a river. On the opposite side of this river there is located the city pumping station, and in the grounds near this station there are a large number of well pipes which furnish the city water supply. When I first made tests in this city, a great deal of trouble had been experienced from electrolysis, particularly of the well pipes and suction mains connected to them. The reason for this was that the negative bus-bar in the substation was connected to the tracks directly at the station, and there were no return feeders carried beyond the station, so that all of the current used by the railway system was obliged to return through the tracks and earth. As a result of this construction, a large amount of stray current reached the water piping system throughout the city, flowed toward the railway substation and then left the water pipes to return to the railway return circuit. As a matter of fact, the water pipes entering the pumping station grounds carried a total average current of from 50 to 100 amperes, which left the water piping in the pumping station grounds, and thereby caused the destruction of this piping by electrolysis. In order to remedy these conditions, the railway company repaired all defective track bonding and installed an insulated return feeder system. Insulated feeders, in some cases with resistors in series, were carried from the substation to four points in the track network located at some distance from the station, and the connec-

tion from the tracks to the negative bus-bar at the substation was made through a resistor so proportioned that the tracks in the neighborhood of the substation would not be the point of lowest potential in the track system. After the track feeder resistors had been finally adjusted, there was not a single location at which the pipes were at all times positive in potential to the tracks, and even in the neighborhood of track feeder connection points there was a low voltage of continually reversing polarity, averaging less than one volt. At other locations the water pipes also reversed continually in polarity, or were at all times negative to the tracks.

A comparison of the currents found on the water mains before the railway improvements had been made, and after these were completed, show that the reduction in these currents is very great. For example: A current of 27 amperes was reduced to 1.3 amperes; a current of 33 amperes to 2.4 amperes; a current of 8 amperes to 0.5 ampere; a current of 8 amperes to 0.07 ampere; a current of 18 amperes to 0.6 ampere; and a current of 3.7 amperes to 0.9 ampere. In addition to the large reduction in the amount of current on the water pipes, the remaining relatively small currents reversed more or less continually in direction, whereas the former large currents all flowed in one direction, namely, towards the pumping station grounds. The reduction in electrolysis troubles in this city is therefore very much greater than expressed by the reduction of currents on the water mains, and, in fact, with the continually reversing currents and potentials there should now be little if any trouble. I believe that reference to these results is the best illustration that I can give you of the effectiveness of improvements in the railway return circuit in reducing electrolysis troubles from stray currents due to single-trolley electric railways.

There are invested to-day in this country hundreds of millions of dollars in single-trolley electric railways which operate under franchises permitting them to use this method of operation. The use of the insulated track feeder system is a plan which can be adopted by such single-trolley railways for the purpose of minimizing electrolysis troubles without requiring a change in the system of operation, and at a cost which is well within practical

limits. It should be stated, however, that with the insulated track feeder system the power losses are increased over what they would be if the same amount of copper were employed in parallel with the tracks. This increase in power losses is a necessary and legitimate expense, incurred for the purpose of reducing stray currents through earth and correspondingly reducing injury to underground structures.

## Summary.

Experience shows that an increasing amount of damage by electrolysis is occurring on underground piping systems in many localities throughout the country where adequate measures have not been taken to reduce this damage. The principal and generally the sole sources of stray electric currents causing this damage are the single-trolley direct-current electric railways employing the running tracks in contact with earth as part of the return circuit. Experience extending over many years in foreign countries and over ten years in this country has shown that practicable and economical methods of construction can be applied to such electric railway systems which will remove acute dangers from stray currents to underground piping systems and which will greatly reduce the electrolysis danger in all cases, and in most cases will make this danger negligible. Mitigating methods applied to underground pipes fail to attack the source of the trouble and should be applied only in special cases, if at all, and then only after adequate methods of minimizing the production of stray currents have been applied to the railway system. Metallic connections from underground water pipes to the railway return circuit which cause these pipes to become a substantial part of this return circuit are inadequate for the protection of the pipes, and are frequently dangerous. Such connections greatly increase current flow on pipes, and, while they may afford local protection, they generally distribute electrolysis troubles to other localities where they are more difficult to find, and in this way frequently give a false impression of immunity. Metallic connections from water pipes to the railway return circuit should generally not be permitted and in no case unless a careful study of conditions has shown that no serious danger will be produced. Such connections

should never be applied to an underground piping system as the principal means of electrolysis mitigation.

In view of the fact that the railway companies in common with the pipe-owing companies are public utilities operating under public franchises and utilizing city streets, it is the duty of both of these utilities to coöperate in order that the causes and extent of any danger from stray currents can be more readily ascertained. Further, the satisfactory solution of the electrolysis problem is one which requires the coöperation of all of the interests concerned. I think that in the past the red flag has been waved too much, and some owners of underground properties have made unreasonable demands, with the result that the electric railway companies have been afraid to coöperate for fear that they would be asked to make excessive expenditures. There is no real reason for this. Electrolysis is an engineering problem, and can be handled by engineering methods in such a manner that no hardship need be imposed nor should be imposed on any one. There is no reason why the negative feeder system should not be laid out along the same engineering lines as the positive feeder system. I think that if the electric railway companies would realize this and the owners of underground properties would coöperate in a practical way, we could obtain a satisfactory and practical solution of the electrolysis problem. For instance, it often happens that the judicious installation of a few insulating joints will save a lot of money in railway track feeders, and in such cases such joints should be installed.

A most important step towards securing the coöperation, which is absolutely necessary in order to obtain adequate and permanent relief from electrolysis, has been made by the formation of the American Committee on Electrolysis. This committee includes representatives of the electric railway, water, gas, electric light, and telephone interests. This committee was organized in 1913 and has completed a preliminary report setting forth the facts regarding electrolysis, upon which the representatives of all of the varied interests have agreed. The committee has already accomplished a great deal towards producing a closer coöperation between the interests owning the electric railways and those owning the underground structures, and it is to be hoped that the

future work of this committee will result in the unanimous adoption of recommendations which will reasonably safeguard underground piping systems against electrolysis.

## Discussion.

Mr. William F. Sullivan.* I would like to ask Professor Ganz what is the danger, if any, of connecting transformer secondaries to service pipes?

Professor Ganz. Ordinarily, there is no danger in connecting transformer secondaries to water pipes, and I have generally recommended it.

Mr. George Cassell.† I would like to know what would be the result of grounding cables from the transformers to water mains instead of house service pipes, providing anything happened to cause current to pass over that line to the main.

Professor Ganz. There ought not to be any material difference between grounding a transformer secondary to a service pipe, or grounding it to a main. It sometimes happens that a service pipe makes a rather high resistance contact with the main, but that is rare. On the other hand, a connection to a service pipe can be readily inspected, whereas in the case of a main, an examination cannot be made.

Mr. Cassell. I remember my first experience was in trying to stop electrolysis on a service pipe that went underneath the rails, and I attempted to dissipate it by putting a rubber jacket over the pipe; but I very soon found I was merely driving it from one place to another, so I quit.

Mr. Morris Knowles.‡ Regarding the grounding of the generating system of a telephone company in their own exchange building. Does that come under a different class?

Professor Ganz. I do not believe that there is any danger connected with that. It is merely a circuit for ringing bells, and the currents used for that purpose are so small compared with those used in electric railway circuits that they are negligible.

---

* Engineer and Superintendent, Pennichuck Water Works, Nashua, N. H.
† Commissioner of Water Works, Chelsea, Mass.
‡ Consulting Engineer, Pittsburgh, Pa.

MR. G. A. CALDWELL. A lead joint sometimes acts practically as an insulating joint, or becomes so through the lead or jute keeping the bell and spigot ends of the pipe apart.

What would be the effect of bonding one pipe to the other with copper wire, and carrying the electricity along the line until you wished to take it from the pipe, and not allowing it to leave one section of the pipe until it had arrived at the point where you wished to have it leave?

PROFESSOR GANZ. If you could connect across every joint of a piping system with a heavy copper wire, and be sure that good contact was maintained, and if there were no other underground pipes or cable systems in the neighborhood, it would be possible to safeguard that particular piping system. But those conditions do not exist in practice. We have to deal with a variety of neighboring underground structures, and we must not make one piping system a serious source of danger to other underground systems.

MR. CALDWELL. Would the fact that the cast-iron pipe was carrying water make it a better conductor than a wrought-iron pipe?

PROFESSOR GANZ. The resistivity of water is so great compared with that of iron that it would have no appreciable effect on the resistance of the pipe.

MR. PATRICK GEAR.* The only trouble we have had from electrolysis is that the insurance companies penalize us because we haven't made an examination or a survey. We never have had any trouble with electrolysis, that I know of. Some years ago I had a break in a pipe about three miles from a railroad of any kind, and the man who was fixing the pipe got a shock, and we thought for a while he was gone. I wondered what the trouble was, and they said it was electrolysis, but I don't know where it could have come from. The place was three miles away from a railway.

PROFESSOR GANZ. In a survey which I made, this past summer, on a pipe line several hundred miles long, we found stray electric currents at points on the pipe many miles distant from any electric railway. I have found similar conditions on many other pipe lines.

* Superintendent of Water Works, Holyoke, Mass.

MR. FRANK L. FULLER.* At Wellesley we have two trolley systems which cross each other in one of the villages, and for more or less distance the rails are over the main pipes, and, of course, cross a good many service pipes; but we have never had any trouble from electrolysis. Those roads must have been running, one of them for fifteen or eighteen years, and the other one, perhaps, for ten years.

At Marblehead, about two years ago, there was a 10-in. pipe, which must have been, I should say, 2 000 ft. from the nearest trolley line, where there was trouble which was thought to come from electrolysis. The pipe, I believe, passed through some rather boggy, low land, and it is possible that the trouble came from that. The general opinion was that the trouble was due to electrolysis. They also have a good deal of pipe that is very much nearer to the railroad tracks than this particular pipe to which I have referred. I suppose this trouble might have been from electrolysis, although the car line is so far away.

PROFESSOR GANZ. Yes. One of the pipe lines I spoke of before crossed a number of trolley tracks, but the worst corrosion occurred not under any of the tracks, but in a field at least one thousand feet away from the tracks. This was undoubtedly due to the fact that the ground in this field was wetter and more acid on account of the refuse from farm animals. It should be emphasized that whatever soil conditions are conducive to chemical corrosion are also conducive to electrolysis.

I would like to ask the gentleman whether the water mains he spoke of were laid before the trolley tracks were laid.

MR. FULLER. Yes.

PROFESSOR GANZ. I have found a number of cases where mains had been laid a number of years before there was any trolley service, and where these mains became coated with oxide which later appeared to protect them when the trolley system started operation. I have one case in mind, where there were some old cast-iron mains, probably fifty years old, in localities where new pipe was corroded very rapidly by electrolysis, while these old mains were not affected.

MR. FULLER. I should like to say, in addition, that of course

*Civil Engineer, Boston, Mass.

we have laid a good many pipes since the installation of the electric roads, and there has been no trouble with those either.

PROFESSOR GANZ. They are probably connected with the old mains, are they not?

MR. FULLER. Yes, they are.

PROFESSOR GANZ. If the greater part of the network was of old pipe, the oxide coating would tend to prevent these mains from gathering stray current, and in this way would help protect the new pipe.

A MEMBER. I wonder whether you would care to express an opinion as to the advisability of making a survey, in a city, of a water-works system.

PROFESSOR GANZ. It is always advisable, because until you do make a survey you have no idea what the conditions are; and, if you have trouble, and quick repairs are made, you cannot tell whether the trouble was due to electrolysis or not. Furthermore, my experience has been that when the railway companies know that the water and gas interests are making surveys of their systems and finding out what the stray current conditions are, they will of their own accord take greater care of their return systems.

# PROCEEDINGS.

## March Meeting.

Hotel Brunswick,
Boston, Mass., March 14, 1917.

The President, Mr. Caleb M. Saville, in the chair.
The following members and guests were present:

### Honorary Members.

E. C. Brooks. A. S. Glover. F. E. Hall. R. J. Thomas. — 4.

### Members.

L. M. Bancroft.
F. A. Barbour.
G. H. Bean.
C. S. Beaudry.
A. E. Blackmer.
J. W. Blackmer.
George Bowers.
Bertram Brewer.
Geo. A. Carpenter.
George Cassell.
J. C. Chase.
H. W. Clark.
F. L. Cole.
J. E. Conley.
John Cullen.
W. R. Edwards.
E. D. Eldredge.
R. H. Ellis.
G. F. Evans.
S. F. Ferguson.
F. L. Fuller.
Patrick Gear.
H. T. Gidley.
F. J. Gifford.
J. A. Gould.
C. R. Gow.
R. K. Hale.
H. A. Hanscom.
A. R. Hathaway.
D. A. Heffernan.
C. R. Hildred.
W. F. Howland.
W. F. Hunt.
C. E. Johnson.
G. A. Johnson.
W. S. Johnson.
J. W. Kay.
E. W. Kent.
Willard Kent.
Patrick Kieran.
S. E. Killam.
John Knickerbacker.
Morris Knowles.
P. J. Lucey.
W. F. Lumbert.
Thomas McKenzie.
W. A. McKenzie.
H. V. Macksey.
W. E. Maybury.
John Mayo.
F. E. Merrill.
G. F. Merrill.
H. A. Miller.
E. E. Minor.
William Naylor.
T. A. Pierce.
A. E. Pickup.
H. G. Pillsbury.
C. L. Rice.
L. C. Robinson.
J. A. Rourke.
P. R. Sanders.
C. M. Saville.
A. L. Sawyer.
J. E. Sheldon.
C. W. Sherman.
G. H. Snell.
O. H. Starkweather.
W. F. Sullivan.
H. A. Symonds.
Milton Thorne.
C. H. Tuttle.
W. H. Vaughn.
R. S. Weston.
L. J. Wilber.
F. B. Wilkins.
G. E. Winslow.
I. S. Wood. — 78.

ASSOCIATES.

Harold L. Bond Co., F. M. Bates, G. S. Hodge.
Builders Iron Foundry, A. B. Coulters, G. H. Lewis, F. N. Connet.
A. M. Byers Co., H. F. Fiske.
Chicago Pneumatic Tool Co., F. S. Eggleston, Jr.
Darling Pump & Mfg. Co., H. A. Snyder.
Eddy Valve Co., H. R. Prescott.
Hersey Mfg. Co., J. H. Smith.
The Leadite Co., George McKay, Jr.
Lead Lined Iron Pipe Co., T. W. Dwyer.
H. Mueller Mfg. Co., G. A. Caldwell.
National Meter Co., H. L. Weston.
National Water Main Cleaning Co., B. B. Hodgman.
Neptune Meter Co., H. H. Kinsey.
Pittsburgh Meter Co., J. W. Turner.
A. P. Smith Mfg. Co., F. L. Northrop.
Thomson Meter Co., E. M. Shedd.
Water Works Equipment Co., W. H. Van Winkle.
Worthington Pump & Machinery Corporation, W. F. Bird, Samuel Harrison, E. P. Howard. — 23.

GUESTS.

NEW HAMPSHIRE.

*Concord*, H. A. Rowell, engineer.

MASSACHUSETTS.

*Boston*, C. DeWitt Jarvis, engineer outside plant, N. E. Tel. & Tel. Co.; William Spence; W. I. Towne, engineer electrolysis.
*Lowell*, G. H. Brown, water commissioner.
*Manchester*, G. E. Hildreth, commissioner.
*Natick*, William Leahy, superintendent water works.
*Norwood*, J. J. Drummey, commissioner.

RHODE ISLAND.

*East Greenwich*, James Kinloch.
*Newport*, G. N. Buckhout.

NEW YORK.

*Woodhaven*, J. A. Cochran.

PENNSYLVANIA.

*Pittsburgh*, G. F. Magloth. — 12.

The Secretary read the following names of applicants for membership, the applications having been properly endorsed and recommended by the Executive Committee:

*Active* — Harold S. Crocker, Brockton, Mass., city engineer; E. Drinkwater, St. Lambert, P. Q., Canada, consulting and designing engineer; A. J. Mahnken, civil engineer, Weehawken, N. J.; John D. Points, Palatka, Fla., superintendent Palatka Water Works.

*Associate* — Edson Manufacturing Company, Boston, manu-

facturers of gasolene engines, diaphragm pumps, suction hose, and pump material.

On motion of Mr. Frank L. Fuller, the Secretary was directed to cast the ballot of the Association in favor of the applicants, and he having done so, they were declared duly elected members of the Association.

The President announced that the Executive Committee had decided on Hartford, Conn., as the place for the annual convention, to be held in the week beginning September 10.

Mr. William S. Johnson, sanitary and hydraulic engineer, Boston, Mass., presented a paper entitled "Statistics Relating to the New England Water Works Association."

Albert F. Ganz, M.E., professor electrical engineering, Stevens Institute of Technology, and consulting engineer, Hoboken, N. J., spoke on "Electrolysis — Troubles Caused thereby and the Remedies which may be Applied." Mr. George Cassell, Mr. William F. Sullivan, Mr. G. A. Caldwell, Mr. Patrick Gear, Mr. Frank L. Fuller, and others took part in the discussion which followed; and, on motion of Mr. Cassell, a rising vote of thanks was given Professor Ganz.

Mr. William S. Johnson, for the Committee on Service Pipes, submitted the final report of the committee. On motion of Mr. Frank L. Fuller, the report was accepted and the committee discharged.

Adjourned.

## EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., March 7, 1917.

Present: President Caleb M. Saville, and members Samuel E. Killam, Henry V. Macksey, Percy R. Sanders, William F. Sullivan, Frank J. Gifford, A. R. Hathaway, Willard Kent, Richard K. Hale, Lewis M. Bancroft, and George A. King, and, by invitation, William S. Johnson and William F. Woodburn.

On motion of Mr. Killam, it was voted: That a committee of three be appointed by the President to consider the subject of meetings.

Voted: That a committee of three be appointed by the President to take measures to increase the membership.

On motion of Mr. Killam, seconded by Mr. Bancroft, it was voted: That a committee of three be appointed by the President to investigate and report at the next meeting of the Executive Committee as to the most desirable place for holding the next annual convention, the expense of said committee to be paid by the Association.

On motion of Mr. King, it was voted: That the details of arrangements for the annual convention be referred to a Committee of Arrangements to be hereafter appointed.

President Saville subsequently appointed as a Committee on Membership, Samuel E. Killam, Percy R. Sanders, and Henry B. Machen.

Committee to investigate and report on most desirable place for next annual convention, William F. Woodburn, William S. Johnson, and Frank J. Gifford.

Mr. Charles E. Coyne, Secretary of Chamber of Commerce of Holyoke, Mass., and Mr. Mandel Sener, Manager of Publicity Bureau of Hartford, Conn., appeared before the committee and spoke of the hotel accommodations to be had in the cities they represented.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., Wednesday, March 14, at 11 o'clock A.M.

Present: President Caleb M. Saville, and members Samuel E. Killam, Frank A. Barbour, Thomas McKenzie, William F. Sullivan, Frank J. Gifford, A. R. Hathaway, Richard K. Hale, H. V. Macksey, Lewis M. Bancroft, Willard Kent, and, by invitation, William S. Johnson and Charles W. Sherman.

Four applications for active membership and one for associate were received and they were by unanimous vote recommended therefor:

Harold S. Crocker, city engineer, Brockton, Mass.; Ernest Drinkwater, municipal engineer, St. Lambert, P. Q., Canada; A. J. Mahnken, C.E., Weehawken, N. J.; John D. Points, superintendent water works, Palatka, Fla.

Associate: Edson Manufacturing Company, Boston, Mass.

A letter from Mr. F. H. Newell, Secretary of the Association for Engineering Coöperation, asking that a delegate be appointed to the next meeting of that association, was read, and Mr. John W. Alvord was, by vote, made the representative of this Association for that purpose.

Mr. Frank J. Gifford, of the committee appointed to investigate the accommodations to be had in different cities for the next annual convention, reported in favor of Hartford, Conn. The report of said committee was, by unanimous vote, accepted.

On motion of Mr. Killam it was voted: That the next Annual Convention of the New England Water Works Association be held at Hartford, Conn., during the week beginning September 9, 1917, the number of days' duration to be at the discretion of the Committee of Arrangements to be hereafter appointed.

On motion of Mr. Killam, it was voted: That the President appoint a committee of five who, with the President, Secretary, and Treasurer, are to constitute a Committee of Arrangements for the next Annual Convention.

The President subsequently appointed the following committee; William S. Johnson, Henry V. Macksey, Samuel E. Killam, Charles W. Sherman, Henry R. Buck, President Saville, Secretary Kent, and Treasurer Bancroft to be members *ex officio*.

Adjourned. Attest: WILLARD KENT, *Secretary*.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., May 2, 1917.

Present: President Caleb M. Saville, and members Samuel E. Killam, Henry V. Macksey, Percy R. Sanders, William F. Sullivan, Frank J. Gifford, A. R. Hathaway, Richard K. Hale, Lewis M. Bancroft, George A. King, Willard Kent; also W. S. Johnson and C. W. Sherman of the Committee of Arrangements for the Annual Convention.

Editor Hale tendered his resignation on account of his military duties.

On motion of Mr. Macksey, the following resolution was unanimously adopted.

*Resolved:* That the resignation of Major Hale, by reason of his being called to military duty, be and hereby is accepted, to take effect at such time as he leaves for active service, with full appreciation of the able and satisfactory manner in which he has performed the duties of Editor, and the hope that he may soon return to resume those duties.

Mr. William S. Johnson was unanimously elected Editor of the Association to fill the vacancy caused by Mr. Hale's resignation.

The question of omitting the June outing and the Annual Convention of the Association on account of the declaration of war was discussed and decided in the negative.

On motion of Mr. Macksey it was voted: That the Committee on June Outing be instructed to confer with the Committee of the Boston Society of Civil Engineers with reference to a joint meeting; if such is found undesirable, the committee is to arrange, should they deem it advisable, for a meeting at which papers may be presented or discussion had on the subject of " War Measures for Protection of Water Supplies."

Voted: That Mr. W. S. Johnson be and hereby is made a committee, duly authorized and with full power, to transfer to the Boston Society of Civil Engineers the pamphlets now occupying the bookcase recently purchased by them, reserving only such as may in his judgment be of special value to members of this Association.

The report of Mr. John W. Alvord, delegate of this Association to the Chicago Conference on Engineering Coöperation, was read, accepted, and ordered placed on file.

The subject of the recent death of Mr. Albert S. Glover, honorary member of this Association, was introduced by Mr. Macksey, and remarks were made by the members present expressing their own grief and feeling of personal loss, their recognition of the loss sustained by the Association, and their appreciation of his unfailing devotion to its interests.

Mr. Macksey then presented a resolution on the death of Mr. Glover, which was unanimously adopted.*

Messrs. R. C. P. Coggeshall, Charles W. Sherman, and J. C. Whitney were, by vote, constituted a committee to prepare a memoir of the late Mr. Albert S. Glover for publication in the JOURNAL of the Association.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

* The resolution will be found on page 321.

## ALBERT SEWARD GLOVER.

CHARTER, ACTIVE AND HONORARY MEMBER OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

Born April 6, 1855. Died April 23, 1917.

ALBERT S. GLOVER was born at South Boston on the date noted above. His father was Albert Henry Glover, originally of Ipswich, Mass., and his mother was Mary Ann Wilson, of Salem. His parents moved to Cottage Farm when he was a young boy, and to West Newton in 1864. For many years Mr. Glover's father was master builder for the Boston & Albany Railroad, having charge of the construction of various wooden bridges and buildings, some of them very large.

Albert S. Glover attended the Newton High School, where he was a leader in athletics, particularly in baseball and football. He was graduated in 1873, being a classmate of John A. Gould. In the fall of that year he entered the Massachusetts Institute of Technology with the class of 1877, having as classmates Prof. George F. Swain, Richard A. Hale, Henry H. Carter, Joseph P. Gray, Charles F. Lawton, George W. Kittredge, the late E. H. Gowing, and other well-known engineers.

In 1875, when work on the Sudbury Water Works for the City of Boston was actively begun, Mr. Glover left the Institute and took a position on the engineering force, being associated with Frederic P. Stearns, George S. Rice, Wilbur F. Learned, and others. A little later he was assigned by the engineer, Mr. Alphonse Fteley, to act as his secretary, and as assistant to the paymaster and purchasing agent; and in 1879 he became paymaster and purchasing agent. In July, 1879, he was elected water registrar of the City of Newton — the executive officer of the Water Department — and held that position until January 1, 1890, when he resigned to become secretary of the Hersey Manufacturing Company, having charge of sales of Hersey meters in New England. To this work he devoted the remainder of his life. He was also clerk of the Common Council of Newton from 1882 to 1887.

Mr. Glover was married, on September 21, 1875, to Mary Wales Robinson, of Newton, who survives him, with their daughter, Mary Wales Glover, a graduate of Smith College.

He was a member of the following societies and clubs, in addition to the New England Water Works Association: American Water Works Association, Boston Society of Civil Engineers, Newton Club, Boston City Club, Engineers Club, Hunnewell Club, Middlesex Club, Economic Club, Bostonian Society, Brae Burn Country Club, Tedesco Country Club.

His activities with this Association are of particular interest to us. His deep concern in its affairs covers the entire range of its existence. Prominent in its organization, on July 21, 1882, he remained an active member until February 10, 1915, when he was named an honorary member. His death reduces the number of living charter members to three. Mr. Glover possessed a well-ordered mind and was recognized as a skillful organizer and leader. He had a decided talent in naming the right man to to take charge of special investigations.

He was Secretary of this Society, 1884–87; Treasurer, 1887–89; Editor, 1884–86, and Junior Editor, 1889–91. His early activities resulted in inducing a large number of the better-known water officials throughout the country to join the Association, and during the existence of the organization he has probably influenced more to become members than has any other member.

The scheme of presenting the transactions of this Asssociation in the form of a quarterly publication was first conceived and suggested by Mr. Glover in 1886, when he then outlined the plan in detail, which included the addition of an up-to-date index from time to time. The JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION is the result; and every member will testify to the value of the index.

His interest and enthusiasm has never faltered. From soon after his connection with the Hersey Manufacturing Company, he declined all official connections, but he continued to be a silent, influential worker. He was probably the best-informed member as regards incidents, happenings, and procedure in past meetings; and was also an authority in parliamentary rules and methods. He was such a walking encyclopedia in these matters that he was

ALBERT S. GLOVER.

Charter Member N. E. W. W. A., June 21, 1882.

Honorary Member, February 10, 1915.

constantly sought by the numerous committees for information and counsel.

The Executive Committee of this Association has expressed its sense of the loss suffered by the Association and its members in the following resolution:

*Whereas*, since last the Executive Committee of the New England Water Works Association met there has passed away one of the charter members of the Association, and feeling our great loss as we do, we cannot allow this meeting to close without placing upon record some expression of the sorrow which oppresses us;

*Therefore be it resolved*, that this committee realizes that when death came to Albert S. Glover, our Association lost one of its most valuable members. The committee also realizes that each of its members has lost a true friend, one who was always ready to advise and assist when needed.

His record for sterling integrity, his high standard of honor, and his absolute fairness in all his business affairs have elevated the standard of the water-works business in New England, and is an inspiration to all who have had the good fortune to be associated with him.

The memory of his many good deeds will remain with us through all the years.

*Be it further resolved*, that the committee wishes to convey its most heartfelt sympathy to his family, and that the President be instructed to send to Mrs. Glover a copy of these resolutions.

Mr. Glover possessed a very sympathetic as well as a very sensitive nature. The generosity of his sympathy to his friends who were in trouble was well known, and a quiet talk with " Bert " was sure to leave the friends more buoyant with the perfume of good cheer, in a way that held them to him with " hooks of steel " and rendered him their helper, comforter, and friend.

Your committee have taken up this study with heavy hearts. It is indeed sad to realize that a spirit, so brave, cheery, and sunny, is to be with us no more. We keenly realize that the Association has lost one of its most trusted and faithful workers, and that each of us has lost a loyal and true friend.

R. C. P. Coggeshall,
Charles W. Sherman,
John C. Whitney,
*Committee.*

# New Members!

**Order your certificate of membership and the Association button Now.**


## INDEX OF ADVERTISERS.


| | PAGE. |
|---|---|
| Ashton Valve Co. | xv |
| Buffalo Meter Co. | ix |
| Builders Iron Foundry | xi |
| Chadwick-Boston Lead Co. | xxiv |
| Chapman Valve M'f'g Co. | xviii |
| Clark, H. W. Co. | xii |
| Coffin Valve Co. | xxv |
| Conard, Wm. R. | xii |
| Dixon, Jos., Crucible Co. | xii |
| Donaldson Iron Co. | xxi |
| Eddy Valve Co. | xx |
| Engineering Record, The | xxviii |
| Fox, John & Co. | xxii |
| Hays M'f'g Co. | xiii |
| Hersey M'f'g Co. | iv |
| Hill, Nicholas S., Jr., & S. F. Ferguson | xii |
| Houdlette, Fred A., & Son | xii |
| Lead Lined Iron Pipe Co. | xxiii |
| Leadite Co. | xxvi |
| Lock Joint Pipe Co. | xxvii |
| Ludlow Valve M'f'g Co. | xvii |
| Metcalf & Eddy | xii |
| Michigan Pipe Co. | xxx |
| Mueller, H. M'f'g Co. | xiv |
| National Meter Co. | ii, iii |
| National Water Main Cleaning Co. | xv |
| Neptune Meter Co. | vi |
| New York Continental Jewell Filtration Co. | xxi |
| Norwood Engineering Co. | xix |
| Pitometer Company | x |
| Pittsburg Meter Co. | vii |
| Rensselaer Valve Co. | xxix |
| Ross Valve M'f'g Co. | xv |
| Smith, The A. P. M'f'g Co. | xxiii |
| Smith, B. F. & Co. | xii |
| Thomson Meter Co. | v |
| Union Water Meter Co. | x |
| U. S. Cast Iron Pipe and Foundry Co. | xxii |
| Warren Foundry and Machine Co. | xix |
| Wood, R. D. & Co. | xvi |
| Worthington, Henry R. | viii |


*(Classified index on page xvii.)*

# Water Meters

**FOR ALL WATER WORKS SERVICE**

**All Sizes, 5-8 to 60 inches**

*CROWN*
*EMPIRE*
*NASH*
*GEM*
*PREMIER*

**With the only reliable straight-reading register in the market**

## National Meter Company

**84-86 CHAMBERS STREET**
**NEW YORK CITY**

BOSTON 159 Franklin St. | CHICAGO 1223 Wabash Ave. | PITTSBURG 4 Smithfield St. | LOS ANGELES 411 So. Main St.
CINCINNATI 10 West Third St. | SAN FRANCISCO 681 Market St.

# The NASH
## GAS ENGINE and TRIPLEX PUMP

FOR

**Town and Village Water Works and Pumping Service Generally**

CAN BE ADAPTED FOR EITHER GAS OR GASOLENE

## National Meter Company

**84-86 CHAMBERS STREET, NEW YORK**

BOSTON: 159 Franklin Street
PITTSBURG: 4 Smithfield Street
CINCINNATI: 10 West Third Street
CHICAGO: 1223 Wabash Ave.
SAN FRANCISCO: 681 Market Street
LOS ANGELES: 411 South Main Street

# APPROVAL

## HERSEY DETECTOR METER

The Hersey Detector Meter has been accepted for eleven years in 3", 4", 6", 8", 10" and 12" sizes without any restrictions or conditions of any kind by every Insurance Company, Stock and Mutual, doing business in the United States, and by the Water Departments and Water Companies in more than 500 Cities and Towns for use on over 3,000 Fire Services protecting nearly $2,000,000,000. worth of Insured Property.

HERSEY MANUFACTURING COMPANY

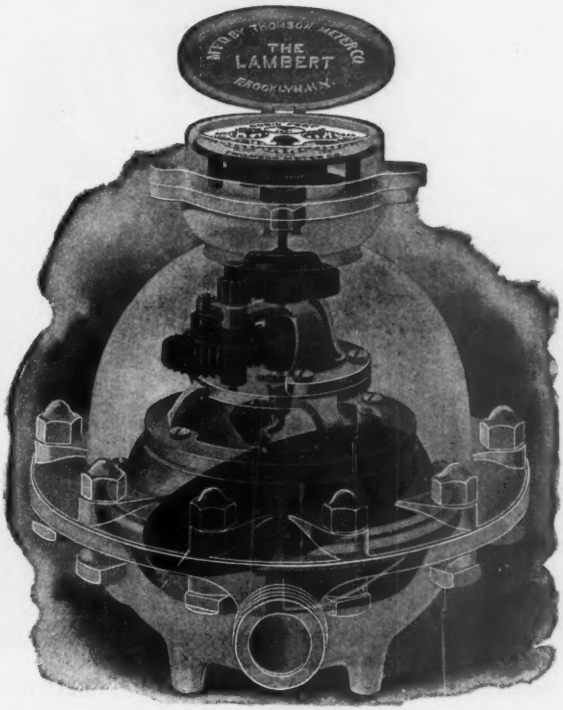
| | | |
|---|---|---|
| BOSTON | COLUMBUS, O. | SAN FRANCISCO |
| NEW YORK | PHILADELPHIA | LOS ANGELES |
| CHICAGO | ATLANTA | PORTLAND, ORE. |

# ACCURACY, LONG LIFE,

## Avoidance of Repairs

Are the Requisites of the Perfect Water Meter and are the Principal Features of the

**"LAMBERT."**



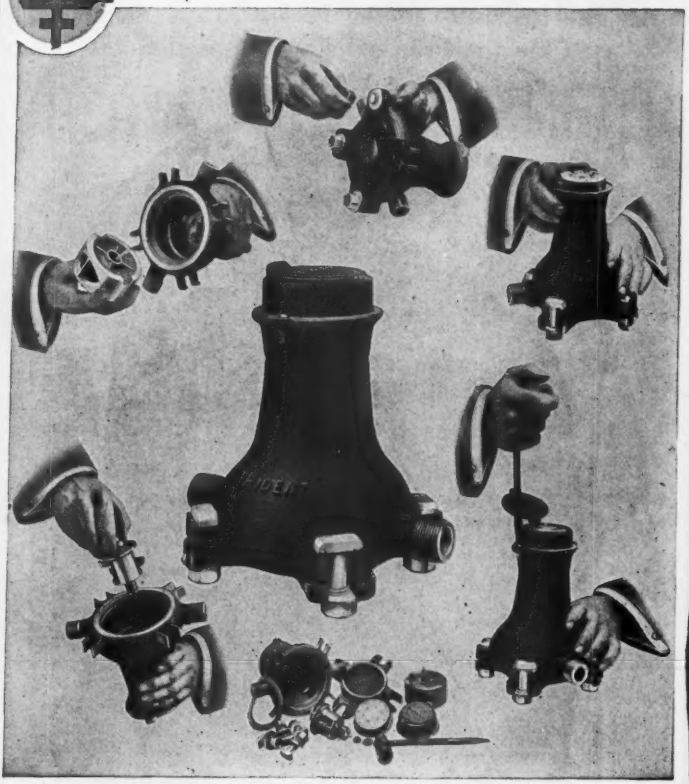

Our unbreakable disk-piston, reinforced with an internal steel plate, can be found only in the **LAMBERT METER.**

The growing popularity of the water-meter system is attributed by many to the inherent excellence of the **"LAMBERT"** meter. Where **"LAMBERT"** meters are selected, success is assured.

**THOMSON METER CO.**

**100-110 BRIDGE ST.**
**BROOKLYN, N. Y.**

# TRIDENT WATER METERS



## Assembling Simplicity of Trident Construction

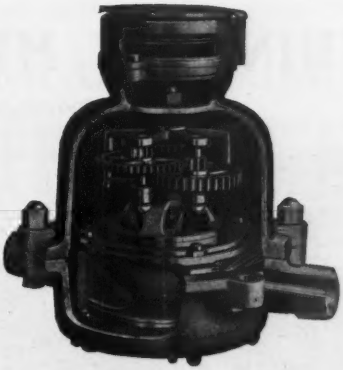
The above cut shows a Trident-Disk Meter dismantled and the extreme ease with which it can be assembled, by first putting in the gear train, then the disk-chamber, the frost bottom next, then the register and register box and the meter is complete. The Trident combination wrench is the only tool necessary to use.

## NEPTUNE METER COMPANY

50 EAST 42d STREET NEW YORK

CHICAGO BOSTON SAN FRANCISCO

ATLANTA LOS ANGELES PORTLAND SEATTLE



"KEYSTONE" WATER METER

NEW YORK CHICAGO

Keystone and Eureka

Water Meters

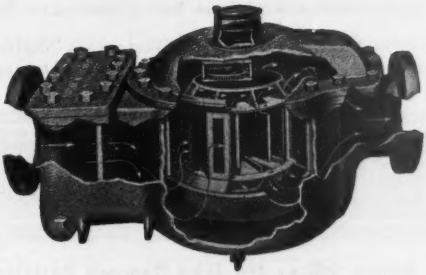
Pittsburgh Meter Co.

East Pittsburgh, Pa.

KANSAS CITY

COLUMBIA, S. C.

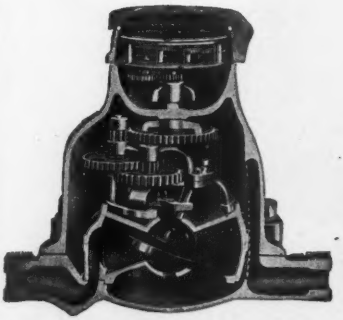
SEATTLE

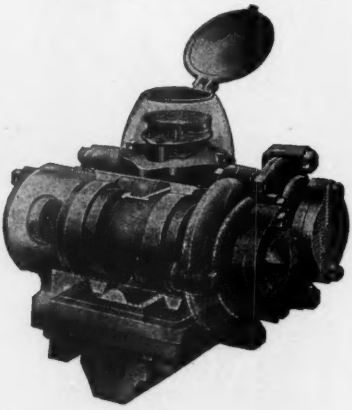


"EUREKA" WATER METER

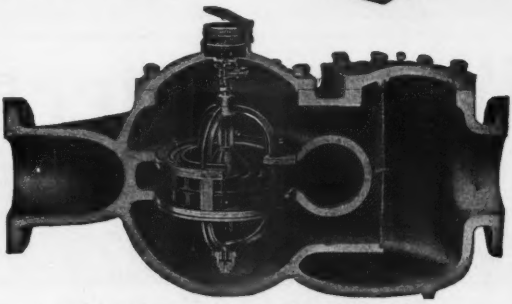
# WORTHINGTON METERS

**The Worthington Duplex Piston Meter** is particularly adapted to large and heavy water works services.





**The Worthington Disc Meter** combines minimum weight with reliability on constant service accuracy of registration.



**The Worthington Turbine Meter** is designed primarily to handle large volumes of water with minimum loss of pressure.

Full descriptions of the different types of Worthington Meters, with tables of sizes and capacities, are given in Bulletin W184–54.

HENRY R. WORTHINGTON

WORKS: HARRISON, N. J. New York Office: 115 Broadway

**Boston Office: 465 John Hancock Building**

W159.8

# AMERICAN AND NIAGARA
# WATER METERS

AMERICAN NIAGARA

## ACCESSIBLE

Our meter may be opened at the bolted flange without disconnecting it from the pipe, each intermediate gear may then be lifted from its bearing and the measuring chamber removed from its seat. No other meter is so simple and accessible for inspection, cleaning or repairing. Sample meter sent to any water works on trial.

**BUFFALO METER CO.**

2917 MAIN ST. EST. 1892 BUFFALO, N.Y.

**UNION ROTARY, COLUMBIA, DISC and NILO (Velocity) WATER METERS**

*Water Pressure Regulators*
*Waste Stops and Corporations*

**UNION WATER METER COMPANY**
**WORCESTER, MASSACHUSETTS**

WATER WORKS SUPERINTENDENTS!

Is your per capita consumption too high?

Do you account for less than 85% of your pumpage?

Are you receiving full revenue from your manufacturing consumers?

If any of these problems confront you, write us at once, without obligation, and let us tell you about our PITOMETER SURVEYS.

THE PITOMETER COMPANY
25 Elm Street (N. Y. Edison Building)
NEW YORK CITY, N. Y.

# ODD SHAPED CASTINGS A SPECIALTY

We are well equipped to make water pipe castings of unusual shapes and sizes, having had a great deal of experience in contract foundry work for many large, well-known companies and for the United States Government.

Globe Special Castings permit the combination of a number of branches in a single casting, avoid useless accumulations of metal, and offer the greatest possible resistance to bursting strains.

Catalogue K sent on request.

# THE VENTURI METER

Measures hot and cold water, sewage, brine, chemical solutions, oil, gas, air and steam. Bulletin 84-W sent on request.

## BUILDERS IRON FOUNDRY

PROVIDENCE RHODE ISLAND

## Metcalf & Eddy

14 Beacon Street, Boston, Mass. — Harris Trust Building, Chicago, Ill.

WATER SUPPLY AND SEWERAGE

Design — Construction
Supervision — Management
Reports — Valuations

## NICHOLAS S. HILL, Jr., and S. F. FERGUSON

Consulting Engineers, Water Supply and Sewage Disposal. Evaluations and Reports. Laboratory for Analysis of Water and Sewage and for Testing Cement, Sand, Coal, and Metals. Steam and Hydraulic Power Plants.

**100 Williams Street, New York**

## H. W. CLARK CO.

**122 South Seventeenth St., Mattoon, Illinois, U.S.A.**

BRANCH OFFICES
NEW YORK SAN FRANCISCO CHICAGO

MANUFACTURERS

The Clark Meter Box — Meter Testers, Service and Valve Boxes, Valve Housings, and most everything for the Water Department.

*Send for catalogues, prices, etc.*

## WILLARD KENT, *Sec'y,*

715 Tremont Temple, Boston, Mass.

*Dear Sir:* Enclosed please find $\frac{\$ .75}{1.50}$ in payment of charge for Certificate $\frac{}{2.25}$ of Membership in the N. E. W. W. Association ($1.50), and Membership Button ($ .75), which please mail me and oblige

Yours truly,

## WILLIAM R. CONARD

Assoc. Amer. Soc. C. E. — Assoc. Mem. Amer. Soc. M. E

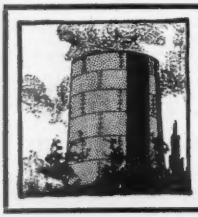
322 High St., Burlington, N. J.

*Inspections and Tests of Materials*

SOUTHERN OFFICE

Maison Blanche Bldg., New Orleans, La.

R. C. HUSTON, C.E., Special Representative



**Standpipes**
**Water Tanks**
**Gas Holders**
and all other metal surfaces need the protection of
**DIXON'S Silica-Graphite PAINT**
BOOKLET NO. 87-B
JOSEPH DIXON CRUCIBLE CO. Jersey City, N. J.

We Carry in BOSTON STOCK for Immediate Shipment

CAST IRON BELL AND SPIGOT
WATER PIPE AND FITTINGS
FLANGED PIPE in full and short lengths
WROUGHT PIPE

FRED A. HOUDLETTE & SON
(Incorporated)

**93 Broad Street, Boston, Mass.**

Quotations furnished promptly for shipment from Foundry

C. D. Kirkpatrick — S. P. Gates
Established 1878

## B. F. SMITH & CO.

Incorporated

Artesian and Driven Wells, Foundation Boring

Engineers and Contractors for Municipal and Private Water Works

First National Bank Building
60 Federal Street — Boston, Mass.

# "The Goods That Please"

## Corporation and Curb Cocks

We have them to meet every requirement

ORIGINAL

## "Hays-Erie"

Extension Service Boxes of proven advantages

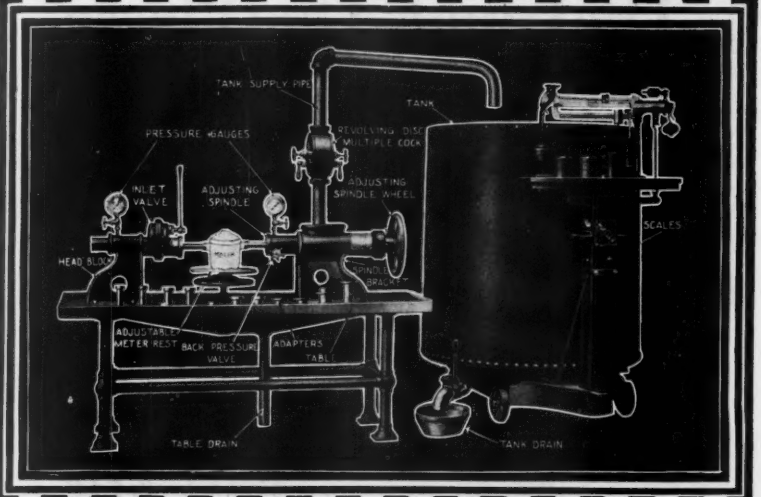
Let us send at our risk, on 30 days' trial, a

## Payne's Patent Tapping Machine

which is recognized to be the most easily operated owing to the few working parts.

**Hays Mfg. Co.,** ERIE PENNSYLVANIA

*Established 1869*




## The People Demand Increased Efficiency

**You can make sure your Department gets full revenue for every gallon of water used—by seeing that all meters are regularly tested for accuracy—with the**

# Mueller Water Meter Tester

**The Mueller will prove exactly what each meter does—will enable you to adjust each meter to absolute accuracy—will save more than its cost year after year. Used and endorsed by leading municipalities. The name Mueller guarantees both Quality and Service.**

**Detailed description and prices on request.**

**H. MUELLER MANUFACTURING CO., Decatur, Illinois**
**Phone Bell 153—Auto 2131**

**Water, Plumbing and Gas Brass Goods**

**New York City, 145 W. 30th St. — Phone, Madison Square 5397**
**San Francisco, 589 Mission St. — Phone Sutter 3577**

© 1917 H MM Co

WATER
FILTERS
REGULATORS
& ENGINES

We make **Pressure Regulating Valves** for all purposes, steam or water.

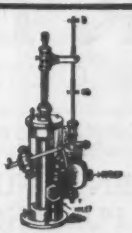
Our **Feed-Water Filter** will keep oil out of your boiler.

We can interest you if you use a condenser.

**Water Engines for Pumping Organs**

**THE ROSS VALVE MFG. CO.**

**TROY, N. Y.**



Standard for pumping church or parlor organs. Ask your organ builder for it or write us.

?

?

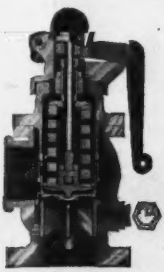
**ENOUGH WATER?**

**If not, it is probably because of lack of carrying capacity of your mains. Consult us.**

**Illustrated booklet upon request**

**NATIONAL WATER MAIN CLEANING CO.**

**50 Church Street New York City**



No. 20. Valve for Stationary Boilers.

*They set the Pace*

**ASHTON POP VALVES and... STEAM GAGES**

No. 74. Recording and Indicating Gage.

Superior in Quality of material and workmanship, and with greatest efficiency and durability, they challenge comparison with any others on the market. Send a trial order subject to approval ONLY IF SATISFACTORY, and thereby prove the claims made for them. HIGH GRADE GOODS OUR EXCLUSIVE SPECIALTY.

**The ASHTON VALVE CO., 271 Franklin Street, BOSTON, MASS.**

S. D. M. J.

# R. D. WOOD & CO.

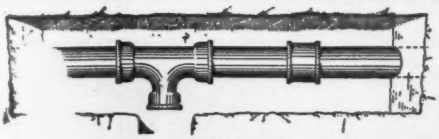
400 CHESTNUT STREET, PHILADELPHIA, PA.

**Engineers, Iron Founders and Machinists**

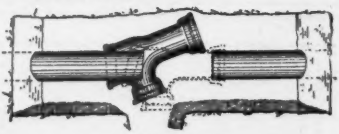
CENTRIFUGAL PUMPS
PUMPING ENGINES

## Cast Iron Pipe

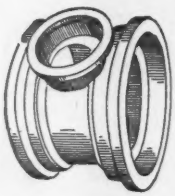
**CUTTING-IN TEES**



*Old Way*



*Our Way*



Connections economically and easily made with one fitting. Saves sleeve, cuts, lead and unnecessary work and material.

**"Reduced Specials"**

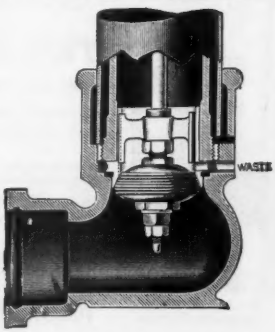
Cost of fittings reduced from 25% to 50%. Full strength. Deep bells. Convenient to handle. Sold by the piece.

## Mathews Fire Hydrants

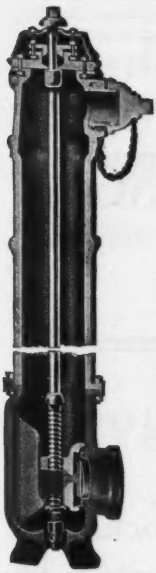
A half century of use has established their reputation as being the most economical, durable and simple hydrant.

**Number in use exceeds total of all other makes combined.**

## Gate Valves




R. D. WOOD & CO. STANDARD
DOUBLE DISK
ANTI-FRICTION
EXTRA WEIGHT, FINISH
AND MATERIAL



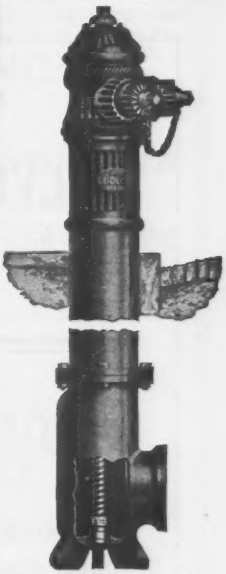
THE LUDLOW VALVE MFG. CO.

MANUFACTURERS OF

VALVES and FIRE HYDRANTS

This hydrant is anti-freezing, because when the drainage is good no water is left in it to freeze.

The drip is directly in the bottom of the hydrant and drains perfectly. It is protected by its valve, which never leaves its socket and cannot be clogged.



DOUBLE AND SINGLE GATE VALVES,

ALSO CHECK VALVES,

FOOT VALVES.

FIRE HYDRANTS.

YARD, WASH, AND FLUSH HYDRANTS.

☞ SEND FOR CIRCULARS. ☜

OFFICE AND WORKS: FOOT OF ADAMS STREET, TROY, N. Y.

BRANCH OFFICES:

| NEW YORK | PHILADELPHIA | BOSTON | PITTSBURGH | CHICAGO | KANSAS CITY |
|---|---|---|---|---|---|
| 92 GOLD ST. | HARRISON BLDG. | OLIVER BLDG. | 1ST NAT. BANK BLDG. | THE ROOKERY | VICTOR BLDG. |


## CLASSIFIED DIRECTORY OF ADVERTISEMENTS.


| | PAGE. |
|---|---|
| **ARTESIAN AND DRIVEN WELLS.** | |
| B. F. Smith & Co. | xii |
| **BRASS GOODS.** | |
| Hays M'f'g Co. | xiii |
| H. Mueller Mfg. Co. | xiv |
| The A. P. Smith M'f'g Co. | xxiii |
| Union Water Meter Co. | x |
| **CAST IRON PIPE AND SPECIALS.** | |
| Builders Iron Foundry | xi |
| Donaldson Iron Co. | xxi |
| John Fox & Co. | xxiii |
| Houdelette, Fred A., & Son | xii |
| U. S. Cast Iron Pipe and Foundry Co. | xxii |
| Warren Foundry and Machine Co. | xix |
| R. D. Wood & Co. | xvi |
| **CLEANING WATER MAINS.** | |
| National Water Main Cleaning Co. | xv |
| **ENGINEERS** | |
| Hill, Nicholas S., Jr., & S. F. Ferguson | xii |
| Metcalf & Eddy | xii |
| **FILTERS AND WATER SOFTENING PLANTS.** | |
| New York Continental Jewell Filtration Co. | xxi |
| Norwood Engineering Co. | xix |
| Ross Valve M'f'g Co. | xv |
| **FURNACES, ETC.** | |
| H. Mueller Mfg. Co. | xiv |
| The A. P. Smith M'f'g Co. | xxiii |
| The Leadite Co. | xxvi |


(*Index continued on page xxv*)

# THE CHAPMAN VALVE MANUFACTURING COMPANY

Manufacturers of

Gate Valves Drip Valves

Gate Fire Hydrants

Corporation Cocks Curb Cocks

Anderson Couplings

Lead Pipe Connections

Trade

Mark

*WRITE FOR OUR WATER-WORKS CATALOG*

Main Office and Works
Indian Orchard, Mass.

BRANCH HOUSES

BOSTON, MASS. 141 High St.
NEW YORK CITY 180 Lafayette St.
PHILADELPHIA 1011 Filbert St.
CHICAGO 116 N. Jefferson St.

NORWOOD ENGINEERING CO.
FLORENCE, MASS.
MANUFACTURERS OF
"IMPROVED" WALKER FIRE HYDRANTS
ALSO THE OLD RELIABLE
"Holyoke" Gate Hydrant
LICENSED MANUFACTURERS OF
The Vivian Rate Controller
WRITE FOR CIRCULARS

# We Want More Members

## Help Us Get Them

**Use Application on Last Page of Advertisements**

Warren Foundry and Machine Co.
SALES OFFICES
11 BROADWAY, NEW YORK
201 DEVONSHIRE ST., BOSTON, MASS.
Telephone, Fort Hill 5951
CAST IRON PIPE
Bell and Spigot Flanged Pipe
Special Castings
Flexible Joint Pipe Cylinders
Water Gas Sewers Culverts
Works, Phillipsburg, N. J.
LARGE STOCK ENABLES US TO MAKE QUICK SHIPMENTS

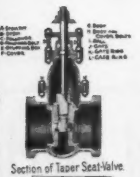
# EDDY VALVE CO.

WATERFORD, NEW YORK U.S.A.

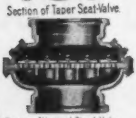
PATENT RUBBER FACED

# EDDY FIRE HYDRANT

VALVE OPEN—DRIP CLOSED.

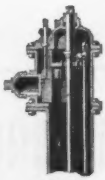


Section of Taper Seat-Valve.



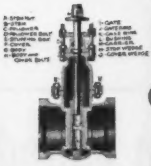
Section of Vertical Check-Valve.

Horizontal Check-Valve.



Hydrant with Independent Nozzle Cut-off.

Hydrant with Water Crane Attachment. Indicator Post.

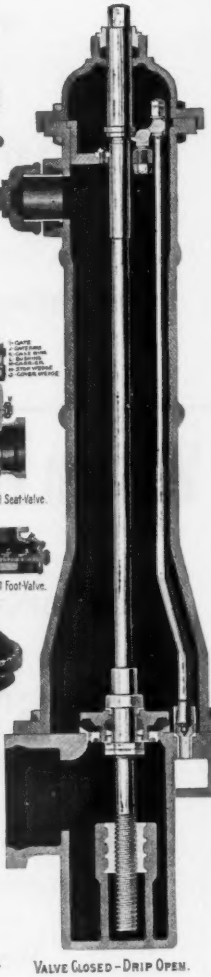


Section of Parallel Seat-Valve.

Section of Vertical Foot-Valve.

Vertical Foot-Valve.

Water Crane with Automatic Drip Valve.



VALVE CLOSED—DRIP OPEN.

All Goods made by the EDDY VALVE COMPANY are manufactured exclusively at WATERFORD, N.Y. U.S.A.

# GRAVITY AND PRESSURE FILTERS

HYPOCHLORITE STERILIZING APPARATUS

***Over 350 Municipal Plants in Successful Operation***

***Total Daily Capacity 900,000,000 Gallons***

## THE NEW YORK CONTINENTAL JEWELL FILTRATION CO.

15 BROAD STREET NEW YORK
111 W. MONROE STREET CHICAGO
313 E. TENTH STREET KANSAS CITY
619 NEW BIRKS BLDG. MONTREAL

# EMAUS PIPE FOUNDRY, DONALDSON IRON CO.,

MANUFACTURERS
...OF...

CAST IRON PIPE

...AND ..

Special Castings for Water and Gas.
Also Flange Pipe, Street Castings,
Manhole Heads and Covers, etc.

JOHN D. ORMROD, President,
J. G. EBERLEIN,
Secretary and Treasurer.

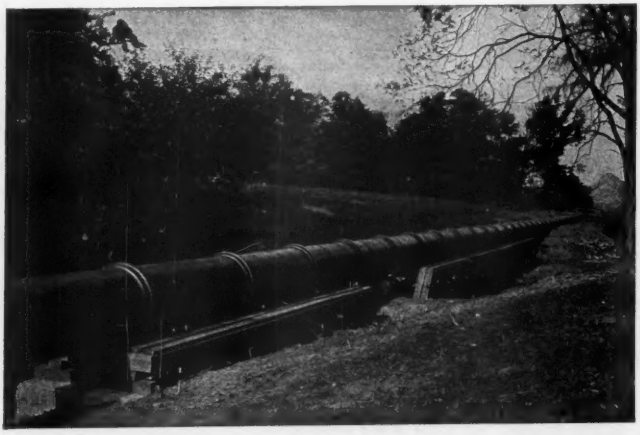
EMAUS,
LEHIGH COUNTY, PA.

# CAST IRON PIPE

ALL REGULAR SIZES, 3 INCHES TO 84 INCHES

FOR WATER, GAS, SEWERS, DRAINS, ETC.

*SEND FOR STANDARD SPECIFICATIONS*



RAILROAD AND TURNPIKE CULVERTS

FLANGE PIPE AND FLANGE FITTINGS

## HEAVY CASTINGS

AND THOSE MADE FROM ORIGINAL DESIGNS

**United States Cast Iron Pipe and Foundry Company**

***SALES OFFICES***

71 Broadway, New York City.
1421 Chestnut Street, Philadelphia, Pa.
Henry W. Oliver Building, Pittsburgh, Pa.
122 South Michigan Boulevard, Chicago, Ill.
520 Security Building, St. Louis, Mo.
American Trust Building, Birmingham, Ala.
799 Monadnock Building, San Francisco, Cal.

# THE A. P. SMITH MANUFACTURING CO.

EAST ORANGE, N. J.

Manufacturers of

Tapping Machines, Fire Hydrants, Water Gates,
Economic Lead Furnaces,
Corporation and Curb Cocks, Brass and Aluminum Castings.
Also General Supplies for Water and Gas Works.

*Write for Catalogue.*

NICHOLAS ENGEL

# JOHN FOX & CO.

## CAST IRON
## WATER & GAS PIPES
## FLANGE PIPE

**Special Castings, Fire Hydrants, Valves**
**General Foundry and Machine Work**
**253 BROADWAY - - NEW YORK CITY**
**Postal Telegraph Building**

HIGHEST AWARD, GOLD MEDAL,
ST. LOUIS EXPOSITION, 1904

Over 100 Water Departments
use
LEAD-LINED IRON and TIN-LINED PIPES
for their service connections

MANUFACTURED BY

# Lead Lined Iron Pipe Company

Wakefield ═══ Mass.

# Chadwick-Boston Lead Co.

**162 Congress St., Boston**

Agents for

## The Celebrated "ULCO"

# LEAD WOOL

**(Every Atom Pure Lead)**

For calking pipe joints under the most difficult conditions.

For overhead joints, or in wet places where the use of molten lead is not only impracticable, but dangerous — **LEAD WOOL** may be employed to advantage. It makes perfectly tight joints to withstand the highest pressures, yet sufficiently elastic to admit of considerable sagging or settling of the pipe without causing the joint to leak. The difference in this respect, as compared with the poured joint, is notable.

**NO FIRE — NO DANGER — NO TROUBLE.**

## *Highest quality* Lead Lined Iron Pipe and Fittings

***Also* Pure Block-Tin Lined Iron Pipe and Fittings**

**Lead Pipe, Tin Lined Lead Pipe, Pure Block-Tin Pipe, Solder Pig Lead, White Lead and Red Lead**

# Coffin Valve Co.

BOSTON, MASS.

Manufacturers of Sluice Gates
Gate Valves
Check Valves
Flap Valves
Foot Valves
Fire Hydrants, etc.

SPECIAL ATTENTION PAID TO WATER-WORKS SUPPLIES FOR CITIES AND TOWNS

Send for Cuts and Prices of our
Type "B" Compression Hydrant and
Type "F" Gate Valves

Hydraulically and Electrically operated valves and sluice gates


## CLASSIFIED DIRECTORY OF ADVERTISEMENTS (*Continued*).


| | PAGE. |
|---|---|
| **GAS ENGINES.** | |
| National Meter Co. | ii |
| **GATES, VALVES, AND HYDRANTS.** | |
| Ashton Valve Co. | xv |
| Chapman Valve M'f'g Co. | xviii |
| Coffin Valve Co. | xxv |
| Eddy Valve Co. | xx |
| John Fox & Co. | xxiii |
| Ludlow Valve M'f'g Co. | xvii |
| Norwood Engineering Co. | xix |
| Rensselaer Valve Co. | xxix |
| Ross Valve M'f'g Co. | xv |
| The A. P. Smith M'f'g Co. | xxiii |
| R. D. Wood & Co. | xvi |
| **INSPECTION OF MATERIALS.** | |
| Wm. R. Conard | xii |
| **LEAD AND PIPE.** | |
| Chadwick-Boston Lead Co. | xxiv |
| Lead Lined Iron Pipe Co. | xxiii |
| **LEADITE.** | |
| The Leadite Co. | xxvi |
| **METERS.** | |
| Buffalo Meter Co. | ix |
| Builders Iron Foundry | xi |
| Hersey M'f'g Co. | iv |
| National Meter Co. | ii |
| Neptune Meter Co. | vi |
| Pitometer Co. | x |
| Pittsburg Meter Co. | vii |
| Thomson Meter Co. | v |
| Union Water Meter Co. | x |
| Henry R. Worthington | viii |


(*Index continued on page xxix.*)

# Twelve Reasons Why

## YOU SHOULD USE

## Trade "LEADITE" Mark

Registered U. S. Patent Office

## FOR

# Jointing Water Mains

1. **DURABILITY.** Leadite joints increase in strength with age.
2. **NO CAULKING.** Leadite joints require no caulking, because the Leadite adheres to the pipe, making a water-tight bond.
3. **COMPARATIVE QUANTITIES.** One ton of Leadite is equivalent to four tons of lead.
4. **LABOR SAVING.** Saves caulking charges and digging of large bell-holes, and reduces the cost of trench pumping to the minimum.
5. **COST.** Its use saves 50 to 65 per cent. over lead, owing to the saving effected in material and labor.
6. **TOOLS.** As no caulking is required, fewer tools are needed.
7. **TRANSPORTATION.** Considerable freight charges are saved because Leadite is lighter than lead.
8. **HAULING.** Saves hauling expense on the work because you move only one fourth the weight of jointing material.
9. **FUEL.** Saves fuel because you melt only one ton of material instead of four, and not as much heat is required either.
10. **DELIVERY.** We can make prompt shipments.
11. **DAMAGE SUITS.** Claims for damages caused by joints blowing out are prevented because Leadite joints will not blow out under any pressure.
12. **USERS.** Progressive water works all over the country use Leadite.

**WRITE FOR BOOKLET**

## THE LEADITE COMPANY, Inc.

**LAND TITLE BUILDING** **PHILADELPHIA**

84-inch Intake made for Public Service Corporation of New Jersey

# MERIWETHER SYSTEM = REINFORCED CONCRETE PIPE

Used by

**Large Manufacturing Companies and others,** for Intakes, Outlets, Culverts, Air Flumes, Cable Conduits, Underground Passages.

Used by

**States, Counties, Towns, Cities,** for Sanitary and Storm Sewers, Water Lines, Culverts, Drains, Wells.

**JUST THE PIPE YOU HAVE BEEN LOOKING FOR**

**LOW COST** — **HIGH EFFICIENCY**

Made in your own city — Keep your money at home

## LOCK JOINT PIPE COMPANY

165 Broadway — New York City

CANADA LOCK JOINT PIPE, Limited
Regina, Sask., Can.

PACIFIC LOCK JOINT PIPE CO.
Tacoma, Seattle, Wash.

The
**Design and Construction**
of
**Water-Works Systems**

and Novel Features in their
Management are given
careful attention by

# Engineering News-Record

It also gives prominence to the
following departments of a
Water-Works System:

DAMS
AQUEDUCTS
PUMPING STATIONS
PIPE SYSTEMS
WATER TOWERS
FILTERS

**SAMPLE COPIES FREE**
**Subscription Price, $5.00 a Year**

ENGINEERING NEWS-RECORD
10TH AVE. AT 36TH STREET NEW YORK

The "COREY"
FIRE HYDRANT

MODERN
SUCCESSFUL
SIMPLE
DURABLE

SUPERIOR

RENSSELAER VALVES

ALL SIZES ALL PRESSURES

WATER, STEAM, GAS, OIL, ETC.

ELECTRICALLY OPERATED VALVES
Check Valves Air Valves
Indicator Posts Valve Boxes

CATALOGUE UPON APPLICATION

RENSSELAER VALVE CO., Troy, N. Y.

BRANCHES

NEW YORK, 50 Church PITTSBURG, 1704 Oliver Bldg.
CHICAGO, 1108-9 Monadnock Block SEATTLE, Arctic Bldg.


## CLASSIFIED DIRECTORY OF ADVERTISEMENTS (*Concluded*).


PAGE.

**METER BOXES.**
Clark, H. W. Co. . . . xii
Hersey M'f'g Co. . . . iv

**OIL, GREASE, ETC.**
Jos. Dixon Crucible Co. . . . xii

**PIPE JOINTS.**
The Leadite Co. . . . xxvi

**PRESSURE REGULATORS.**
H. Mueller Mfg. Co. . . . xiv
Ross Valve M'f'g Co. . . . xv
Union Water Meter Co. . . . x

**PUMPS AND PUMPING ENGINES.**
Builders Iron Foundry . . . xi
National Meter Co. . . . iii
R. D. Wood & Co. . . . xvi

**REINFORCED CONCRETE PIPE.**
Lock Joint Pipe Co. . . . xxvii

**TAPPING MACHINES.**
Hays Mfg. Co. . . . xiii
H. Mueller Mfg. Co. . . . xiv
The A. P. Smith M'f'g Co. . . . xxiii

**TOOLS AND SUPPLIES.**
H. Mueller Mfg. Co. . . . xiv
The A. P. Smith M'f'g Co. . . . xxiii
Hays M'f'g Co . . . xiii
The Leadite Co. . . . xxvi

# MICHIGAN
## COMBINATION STEEL AND WOOD
# WATER PIPE

Look into the water pipe question for work this season, and see why Michigan Combination Pipe is the pipe that fits your needs. Investigate the question and learn that Michigan Pipe can start to leave this factory for your job almost as soon as it is ordered. Know that we will send a man to any part of the country to supervise the laying of Michigan Pipe. And remember—"Steel for Strength-Wood for Durability."

**Read the Whole 17 Service Aids**

(1) Durability—40 years' record
(2) Frostproof
(3) Corrosion-proof
(4) Laid in a Wet Trench
(5) Low Repair Costs
(6) Enduring Strength
(7) Service Connections Easily Made
(8) Preserves Purity of Water
(9) Light Weight (Easily handled)
(10) No Electrolysis
(11) Low Cost of Laying
(12) Low Initial Cost
(13) Greater Carrying Capacity
(14) Nominal Maintenance Costs
(15) Laid by Common Labor
(16) Made by a Firm with 40 Years' Experience
(17) We Help to Lay It

*Write for the Michigan Pipe Book with further facts and many valuable tables.*

**Michigan Pipe Company,** BAY CITY MICHIGAN

**Chicago: 203 South Dearborn Street** **New York: 30 E. 42d Street**
**Chattanooga, Tenn.: 319 Hamilton National Bank Bldg.**
**Cleveland: 208 American Trust Bldg.** **Galveston, Texas: 412 Security Bldg.**

**Fred A. Houdlette and Son, Inc.**
New England Representative
**93 BROAD STREET .·. BOSTON, MASS.**

# New England Water Works Association,

ORGANIZED JUNE 12, 1882.

## APPLICATION FOR MEMBERSHIP.

*I, the undersigned, residing at*.....

*being desirous of admission into the New England Water Works Association, hereby make application for* .....
(resident, non-resident or associate)

*membership.*

*I am*.....*years of age, and I have been engaged in the following named work:*

.....

.....

.....

*I will conform to the requirements of membership if elected.*

*Signed*,.....

*Address*,.....

*Dated*,.....*191*

**Resident members are those residing in New England; all others are non-resident.**
**Entrance fee is $5.00 for resident and $3.00 for non-resident members.**
**Annual dues are $3.00 for both resident and non-resident members.**

## The Journal of the New England Water Works Association

is a quarterly publication, containing the papers read at the meetings, together with verbatim reports of the discussions. Many of the contributions are from writers of the highest standing in their profession. It affords a convenient medium for the interchange of information and experience between the members, who are so widely separated as to find frequent meetings an impossibility. Its success has more than met the expectation of its projectors; there is a large and increasing demand for its issues, and every addition to its subscription list is a material aid in extending its field of usefulness. ALL MEMBERS OF THE ASSOCIATION RECEIVE THE JOURNAL IN PART RETURN FOR THEIR ANNUAL DUES; to all others the subscription is three dollars per annum.

## TO ADVERTISERS

THE attention of parties dealing in goods used by Water Departments is called to the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION as an advertising medium.

Its subscribers include the principal WATER WORKS ENGINEERS and CONTRACTORS in the United States. The paid circulation is OVER 1,000 COPIES.

Being filled with original matter of the greatest interest to Water Works officials, it is PRESERVED and constantly REFERRED TO BY THEM, and advertisers are thus more certain to REACH BUYERS than by any other means.

The JOURNAL is not published as a means of revenue, advertisements being inserted solely to help meet the large expense of publication.

### ADVERTISING RATES.

| | |
|---|---|
| One page, one year, four insertions | Sixty Dollars. |
| One-half page, one year, four insertions | Forty Dollars. |
| One-fourth page, one year, four insertions | Twenty-five Dollars. |
| One-twelfth page (card), one year, four insertions | Ten Dollars. |
| One page, single insertion | Thirty Dollars. |
| One-half page, single insertion | Twenty Dollars. |
| One-fourth page, single insertion | Fifteen Dollars. |

Size of page, 7¾ x 4¾ net.

A sample copy will be sent on application.

For further information, address,

GEORGE A. KING,
Advertising Agent,
TAUNTON,
MASS.

Or, RICHARD K. HALE,
Editor,
715 Tremont Temple, Boston, Mass.


SAMUEL USHER
BOSTON

Sept. 1917

## NOTICE.

The delay in publication of this issue of the JOURNAL is due partly to the departure of Lieut.-Col. Richard K. Hale for service with his regiment in France; and more, to the serious illness and death of Mr. William S. Johnson, who had been elected by the Executive Committee to succeed Colonel Hale as editor.

Mr. Johnson had much of the material in type before he was forced to give up work. The remainder of the work has been done somewhat hastily by a former editor of the JOURNAL, with the assistance of members of the Executive Committee, and of Miss J. M. Ham.

# Table of Contents.


| | PAGE |
|---|---|
| Report of Committee on Service Pipes | 323 |
| Discussion | 346 |
| Rapid Sand Filtration. By George A. Johnson | 390 |
| Discussion | 468 |
| Mechanical Filter Bottoms and Strainer Systems. By Robert Spurr Weston | 474 |
| Discussion | 480 |
| Report of the Joint Committee on Water Consumption | 481 |
| Some Experiences with a Trenching Machine. By George W. Batchelder | 486 |
| Experiences with Universal Cast-Iron Pipe. By John H. Walsh | 490 |
| Discussion | 492 |
| The Results of the Use of Meters in the Metropolitan Water District, Boston. By Samuel E. Killam | 495 |
| Discussion | 506 |
| Proceedings: | |
| Thirty-Sixth Annual Convention | 512 |
| Address by Hon. F. A. Hagarty | 517 |
| Address by Hon. Charles Hopkins Clark | 519 |
| Address by Hon. Charles E. Gross | 522 |
| Address by Mr. James P. Berry | 526 |
| Address by Mr. Frank G. Macomber | 528 |
| Award of Brackett Medal | 531 |
| War-time Construction of Public Works | 536 |
| Executive Committee | 541 |